Automated Snow Depth Collection and Reporting

Requested by
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List of Abbreviations and Acronyms

ARHO	American River Hydrological Observatory
ASWS	automatic snow weather station
BTAC	Bridger-Teton Avalanche Center
Caltrans	California Department of Transportation
CDWR	California Department of Water Resources
DCP	data collection platform
DOT	department of transportation
GNSS	global navigation satellite system
GOES	Geostationary Operational Environmental Satellite
GPR	ground penetrating radar
GPS	global positioning system
HyDAS	Hydrology Data Acquisition System
InSAR	interferometric synthetic aperture radar
IoT	Internet of Things
LiDAR	light detection and ranging
LTAR	Long-Term Agroecosystem Research (U.S. Department of Agriculture)
LWE	liquid water equivalent
MDSS	Maintenance Decision Support System
MDT	Montana Department of Transportation
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NRPA	Norwegian Public Roads Administration
RMSE	root-mean-square error
RTK	real-time kinematic
RWIS	road weather information system
SAIL	Surface Atmosphere Integrated Field Laboratory (Department of Energy)
SAR	synthetic aperture radar
SDRadar	software-defined radar
SfM	Structure from Motion
SNOTEL	Snow Telemetry (Network)
SPLASH	Study of Precipitation, the Lower Atmosphere and Surface for Hydrometeorology (NOAA)
SWE	snow water equivalent

UAS	unmanned aircraft system
UAV	unmanned aerial vehicle
UMBS	University of Michigan Biological Station
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USRP	Universal Software Radio Peripheral
UW	University of Washington
VDC	volts of direct current

Executive Summary

Background

Roadways through mountainous regions of California have locations with historical collection points that require Caltrans staff to measure snow accumulation, snow depth and snowmelt activity during the winter season. Currently, snow depth is manually measured using line of sight to a snow stake. Snow depth, measured daily, routinely reaches 20 feet and may be more in some locations. Hazardous roadway and weather conditions may also necessitate the use of chains to reach measurement sites.

Monitoring data is collected, documented and sent for long-term retention in a Caltrans headquarters database. Many allied agencies, including the National Weather Service, use this information for monitoring climate changes, forecasting and other applications. Staffing challenges, recreational activities near measurement sites and limited line-of-sight access, however, make it difficult to record timely readings in more remote locations. To ensure safety for the public and Caltrans maintenance crews gathering the data, Caltrans District 3 is investigating remote snow depth monitoring practices.

This Preliminary Investigation sought information about best monitoring practices and time-tested measurement products, including research or agency experience that compares manual snow stake readings with automated or remote readings, types and reliability of power sources used in extremely remote locations, and commercial sensors and monitors.

Information for this investigation was gathered through a survey of state departments of transportation (DOTs), Caltrans districts and other public institutions regarding their experiences with remote snow depth monitoring. A literature search that examined relevant in-progress and completed domestic and international research and related resources supplemented survey findings.

Summary of Findings

Survey of Practice

An online survey was distributed to state DOT members of the Clear Roads pooled fund study, selected Caltrans districts, and other public agencies and institutions expected to have experience with remote snow depth collection. Sixteen state DOTs, three Caltrans districts and four other public institutions responded to the survey:

State Transportation Agencies

- Arizona DOT
- Connecticut DOT
- Idaho Transportation Department
- Iowa DOT
- Kentucky Transportation Cabinet
- Massachusetts DOT
- Michigan DOT
- Montana DOT
- Nebraska DOT
- New York State DOT
- North Dakota DOT
- Oregon DOT
- Pennsylvania DOT
- South Dakota DOT
- Texas DOT
- Virginia DOT

Caltrans Districts

- District 2
- District 6
- District 9

Other Public Institutions

- California Department of Water Resources (CDWR)
- National Center for Atmospheric Research (NCAR), National Science Foundation
- Natural Resources Conservation Service (NRCS), U.S. Department of Agriculture
- University of Washington (UW)

The survey received two CDWR responses: Snow Surveys and Water Supply Forecasting Unit (*Snow Surveys*) and Hydrology Section (*Hydrology*). The NRCS responding region includes Oregon, Washington and Northern California.

All responding state DOTs and Caltrans districts do not remotely gather snow depth measurements in the manner envisioned by Caltrans. Some respondents commented briefly on agency snow depth monitoring practices. North Dakota DOT relies on the National Weather Service "after the fact" and the Maintenance Decision Support System Pooled Fund (TPF-5(347)). Texas DOT does not use snow gauges.

New York State DOT uses the MESONET weather station network, which includes a subnetwork of 20 snowpack monitoring sites. Snow depth is remotely monitored every five minutes across select areas of the Adirondacks, Tug Hill and Catskills; snow water equivalent (SWE) is estimated over a six-hour period with observations provided up to four times daily.

Three state DOTs — Arizona, Massachusetts and Pennsylvania — rely on road weather information system (RWIS) sites for snow depth measurement. Caltrans districts use manual snow depth measurement methods such as snow stakes (District 6) and other visual and physical means (District 9).

Five respondents from the four responding other public institutions described remote tools and practices to collect and monitor snow depth data. Survey responses from the five respondents indicating the use of remote snow measuring methods are summarized below in three topic areas:

- General snow depth measurement practices and measurement tools.
- Managing snow depth measurement systems.
- Assessment and recommendations.

General Snow Depth Measurement Practices

The *CDWR/Snow Surveys* and *NRCS* respondents indicated their organizations' current remote snow depth practices started in the 1970s and both continue to modernize and upgrade their equipment. New monitoring stations at NRCS are SNOLITE stations — aerial markers measuring snowpack but not cumulative precipitation or SWE — which can be relatively easily deployed without National Environmental Policy Act (NEPA) regulatory requirements.

The *CDWR/Hydrology* respondent indicated current practices started in the 1980s; current remote measuring practices began at NCAR in 2007. *UW* has used snow depth monitoring in research since 2013, though the protocol for each field experiment changes based on the goals of the research project.

Snow Parameters Measured

Automated measurement capabilities for snow depth range from 10 to 15 feet (*NCAR*) up to a recorded maximum of 235 feet (*NRCS*). *CDWR* can measure depths between 20 and 30 feet and for *UW*, snow depths depend on the height of the sensor.

Three institutions measure snow water content (*CDWR*) and, specifically, liquid water equivalent (LWE) (*NCAR*) and SWE (*NCAR* and *NRCS*). Other snow-related parameters measured by the responding institutions include:

- Precipitation (*CDWR/Hydrology* and *NRCS*).
- Soil characteristics (*NRCS*).
- Solar radiation (*CDWR/Hydrology* and *NRCS*).
- Temperature and relative humidity (*CDWR/Hydrology*, *NRCS* and *UW*).
- Weather characteristics (*UW*).

Remote Snow Depth Measurement

Survey respondents identified tools, timing and number of snow depth measurement sites. Products used in remote measurement and vendor information is summarized in Table ES1. While Campbell Scientific is the most common vendor used by the survey respondents, in most cases, respondents did not identify which models they use. Additional products and additional details on all products are presented in the **Detailed Findings** section of this report.

Table ES1. Remote Snow Depth Measurements

Vendor	Product Description	Institution and Product
Campbell Scientific, Inc.*	• SDMS-40 Multipoint Scanning Snowfall Sensor: Laser-based snowfall sensor • SR50A-EE-L Anodized Sonic Distance Sensor for Extreme Environments: Acoustic-based snow-depth sensor • SR50ATH-L Sonic Distance Sensor with Heater and Temperature Sensor: Heated sonic distance sensor with integrated external temperature probe and heater • CR1000Xe Measurement and Control Datalogger: A low-powered device that measures analog and digital sensors, processes and stores measurements, and adapts to any communications link	• *CDWR/Hydrology*. Unspecified sensors and data loggers (CR1000 (retired per vendor's website), CR1000x (retired per the vendor's website) and CR1000xe). • *CDWR/Snow Surveys*. Unspecified data collection platforms (DCPs). (Vendor's website indicates these are no longer available.) • *NCAR*. Unspecified laser and acoustic sensors and data loggers CR800, 1000 and 1000x. (All three data logger models are retired per the vendor's website.) • *UW*. Unspecified acoustic snow depth sensor.
Geonor, Inc.	SHM31 Snow Depth Sensor: Laser-based snow depth sensor; improved design from the SHM30.	• *CDWR/Hydrology*. SHM31 laser snow depth sensor. • *NCAR*. Unspecified LWE sensor or gauge.
Hydroinnova, LLC	SnowFox: Portable, affordable and highly adaptable sensor capable of measuring SWE over a small area.	*CDWR/Snow Surveys*. SnowFox depth sensors.

Vendor	Product Description	Institution and Product
Judd Communications, LLC	Ultrasonic Depth Sensor: Ultrasonic sensor with integrated temperature probe to calculate temperature compensated distance	• *CDWR/Hydrology*. Upgrading from Judd to Geonor. • *CDWR/Snow Surveys*. Snow depth sensors.
Sommer Messtechnik*	Snow Depth Sensor USH-9: Ultrasonic sensor for non-contact recording of snow depths; robust design and low energy consumption	*NRCS.* Transitioning to USH-9.
Various	Time-lapse camera	*UW*. Cameras and poles used in many remote locations.
Not Known	Unspecified	• *NCAR*. LWE measured with precipitation gauges. • *NRCS*. SWE measured with fluid-filled snow pillow.

* Additional models are described in the **Detailed Findings** section of this report.

The *CDWR/Hydrology* respondent reported that the agency designed, built and coded the remote monitoring system in-house.

The timing of remote snow depth measurements varies by institution:

- Continuous during fall/winter/spring (*CDWR/Snow Surveys*)
- Once per minute (*NCAR*)
- Every 15 minutes (*CDWR/Hydrology*)
- Hourly (*NRCS* and *UW*)

Similarly, data is generally collected every 15 minutes (*CDWR/Snow Surveys*) or hourly (*CDWR/Hydrology* and *Snow Surveys; NRCS;* and *UW*). *NCAR* collects snow depth data every five minutes if a cell modem is connected, otherwise data collection is once or twice a winter.

The number of monitoring sites managed by *CDWR* ranges from 70 (*Hydrology*) to 135 (*Snow Surveys*). *NCAR* uses one to five sites, depending on the field program; likewise, the number of UW monitoring sites varies. *NRCS* manages over 160 automated monitoring stations in the region.

Manual Snow Depth Measurement

In addition to remote or automatic measurement systems, responding institutions identified these methods for manual snow depth measurement:

- Avalanche probes (*UW*).
- Federal samplers (*CDWR/Hydrology* and *Snow Surveys;* and *UW*).
- Snow courses (permanent observation sites) and aerial markers or pipes with cross members that are visible from a flyover (*NRCS*).

CDWR's website describing California's Cooperative Snow Surveys includes data collection methods.

Comparing Manual and Remote Measurements

Most respondents use manual snow depth measurements to verify the accuracy of automated or remote measurements (described in the **Detailed Findings** section of this report). While comparisons between manual and automated measurement vary for some institutions (*CDWR/Snow Surveys*), others provided an error range between manual and automated measurements:

- Between 0% and 20%, depending on the area and the depth of the snowpack, density and compression within the measuring tube (*CDWR/Hydrology*).
- Equal or less than 10%, assuming snowpack is relatively uniform across the site and there are no other onsite issues (*NRCS*).

The NCAR respondent recognized that accuracy must be measured in the immediate vicinity of the automated measurements, and it can be challenging to avoid disturbing the snow around the sensor.

Managing Snow Depth Measurement Systems

Remote snow depth data collection and management involves unique considerations including power sources and outages, system downtime, and managing and verifying snow depth data.

Power Sources*.* All responding institutions use solar panels and batteries are commonly used to power remote snow depth monitoring systems (*CDWR/Hydrology* and *Snow Surveys; NCAR; NRCS;* and *UW*). *NCAR* also operates laser sensors with AC power.

Power Outages. Snow-covered solar panels are a common cause of power outages (*CDWR/Snow Surveys* and *NCAR*). Low power can also cause a monitoring site to go down (*NRCS*). Other potential causes reported by *CDWR*/Hydrology:

- Avalanche damage
- Bear damage
- Devices with heaters that should have been disabled
- Old batteries
- Solar regulator failing
- Water intrusion

System Downtime*.* While minimal for some respondents (*NCAR*) and highly variable for others (*UW*), downtime of snow depth monitoring systems is caused by a variety of factors, including geographic factors or environmental phenomenon (*CDWR/Hydrology*); and site damage, telemetry outage or weather (*NRCS*). At *CDWR*, monitoring site downtime varies from a few days to a week and if a station fails overall, it would be out of commission for the remainder of the season (*Snow Surveys*).

Data Management. Snow depth data are collected through the Geostationary Operational Environmental Satellites (GOES) system by CDWR/Hydrology and NRCS, and stored and managed on various databases, including the California Data Exchange Center (*CDWR/Snow Surveys*), a MySQL server (*NCAR*), and other internal databases (*NRCS*). At *UW*, data management and archive location vary by research project.

Data Verification. Snow depth data collected through automated means is verified manually at most responding institutions (*CDWR/Hydrology* and *Snow Surveys; NCAR;* and *NRCS*). CDWR/Hydrology also verifies remote data through the Airborne Snow Observatory. NCAR uses webcams pointing at rulers and manual stakes to verify remote measurements, and NRCS compares measurements to the period of record to gauge if current data is reasonable.

Assessment and Recommendations

Responding institutions noted several benefits of remote snow depth measuring practices:

- Flexibility to try new instruments while maintaining current tools (*CDWR/Hydrology*)
- Power system and data collection methods are robust and reliable (*NCAR*)
- Wide network coverage across the West (*NRCS*) and within California (*CDWR/Snow Surveys*)

Monitoring station remoteness is a common challenge to access (*CDWR/Hydrology*) and maintain (*CDWR/Snow Surveys* and *NRCS*) snow depth measurement equipment and systems. NCAR finds data transmission to be problematic absent necessary connections and insufficient staff resources hinder NRCS in servicing a large number of sites. Challenges with remote snow depth monitoring vary at UW, depending on the research project.

Respondents offered recommendations for agencies interested in automated monitoring related to where, what and how to remotely measure snow depth:

Monitoring site location. The NCAR representative noted finding a good and representative monitoring station location can be challenging, and recommended scouting potential locations several times during the winter to account for varying snow depths and conditions. The UW respondent recommended flat ground for a stable tower to hold the monitoring instruments and carefully aligning locations with monitoring goals as snow depth varies dramatically in space.

Parameters measured. The CDWR Snow Surveys respondent noted that while snow water content is more trackable and provides a more accurate reading of snowpack than snow depth, measuring both can function as a cross-check. Stable measurements in the same location over time can account for deviations from "normal," according to the UW respondent.

Equipment placement, operation and maintenance. Equipment placement recommendations included ensuring the solar panel tower is tall enough and the sensor is high enough to account for the above-average snowfall winters (*NCAR*) and having the appropriate equipment in place to collect winter data if remote communications are not available (*NCAR*).

The CDWR/Hydrology respondent recommended correctly calculating power needs and disabling the device heaters if necessary to conserve power and running all cables in conduit to avoid water damage. Also recommended are the use of pigtail connector wires on instruments and simplifying configuration management in one program.

Related Research and Resources

A literature search of publicly available domestic and international in-progress and published research and commercial products identified resources that are organized into five categories:

- National Research and Resources.
- State Research and Resources.
- Other Research and Resources.
- International Research and Resources.
- Commercial Products (includes products not addressed in the Measurement Tools and Vendors section of this report).

Tables ES2 through ES6 that summarize these publications by topic area begin on page 12. Each table provides the publication or project title, the year of publication if research is completed, and a brief description of the resource. Significantly more detail about each resource can be found in the Detailed Findings section of this report.

Gaps in Findings

Despite a robust survey response, all 16 responding DOTs and three Caltrans districts (Districts 2, 6 and 9) reported no experience with remote snow depth collection in the manner envisioned by Caltrans. The New York State DOT respondent did note that the agency relies on New York State Mesonet, a network of 20 snowpack monitoring sites that remotely monitor snow depth every five minutes.

Of the four public institutions using automated remote snow depth measuring techniques, two — NCAR and UW — are engaged in more research-oriented monitoring where the number of sites and continuity of measurement vary. While literature is available that describes various remote measurement techniques, published literature on power considerations for monitoring in remote environments is minimal.

Next Steps

Moving forward, Caltrans could consider:

- Reaching out to Bryan Prestel, the CDWR/Hydrology respondent, who has previously worked with Caltrans District 2 and offered to share additional details of CDWR's experience with remote snow measurement.
- Following up with the UW respondent to learn more about the time-lapse cameras used remotely to measure snow depth.
- Engaging with NCAR to learn more about previous research the respondent mentioned that related to the optimal time of day to measure snow depth, and how NCAR collects winter data if remote communications are not available.
- Monitoring Montana DOT's research project exploring a drone to remotely monitor and or map snowpack at hazardous sites.

Table ES2. National Research and Resources

Publication or Resource (Year)	Excerpt from Abstract or Description of Resource
USDA LTAR [Long-Term Agroecosystem Research] Common Experiment Measurement: Snow (2024)	Provides snow depth measurement protocol for manual, semi-manual and automated methods, including equipment, site maintenance and data processing, quality control and data file formats.
Emerging Technologies in Snow Monitoring: Report to Congress (2021)	Summarizes snow depth measurement methods, including automated methods. Tables describe: • Strengths and limitations of nine separate ground-based methods • Strengths and limitations of six air- and space-based methods • Initial snow depth measurement implementation and annual operative costs
Guidelines for Using Photogrammetric Tools on Unmanned Aircraft Systems to Support the Rapid Monitoring of Avalanche-Prone Roadside Environments (2022)	Presents results of photogrammetry software tests to provide snowpack depth and snowpack volume with data from unmanned aircraft above roadside avalanche test sites in Alaska and Washington.

Table ES3. State Research and Resources

Publication or Resource (Year)	State	Excerpt from Abstract or Description of Resource
Snow Depth Retrieval with an Autonomous UAV-Mounted Software-Defined Radar (2023)	Colorado	Describes a field campaign to measure seasonal snow depth at Cameron Pass, Colorado, using a synthetic ultrawideband software-defined radar implemented in commercially available Universal Software Radio Peripheral software-defined radio hardware and flown on a small hexacopter unmanned aerial vehicle.
Snowpack at UMBS (2023)	Michigan	Describes a high frequency snow depth sensor at University of Michigan Biological Station, using a low-cost sonic rangefinder to monitor the distance between the bottom of the sensor and the ground beneath it. The sensor node was designed by the Digital Water Lab in the UM College of Engineering.
Research in Progress: Remote Observation Over Time (Drone in a Box) (expected completion date: 2026)	Montana	Exploring a drone to monitor and/or map snowpack at hazardous sites remotely to reduce crew exposure and assess potential dangers to the traveling public.

Table ES4. Other Research and Resources

Publication or Resource (Year)	Source	Excerpt from Abstract or Description of Resource
Snow Depth Extraction from Time-Lapse Imagery Using a Keypoint Deep Learning Model (2024)	Journal	Presents a keypoint detection model to facilitate automating the process of snow depth extraction from snow poles installed in front of time-lapse cameras; provides a framework for future analysis of snow depth from time-lapse imagery to improve snow depth monitoring and forecasting.
Automated Remote Sensing of Snow Depth (2024)	National Weather Service	Describes a developmental automated snow sensor project in the National Weather Service's Grand Rapids Office in which a snow sensor probe sends ultrasonic pulses to a snow board below and distance is calculated as a function of time and distance.
How We Measure Snowfall: Daily and Season Snow Totals Explained (2023)	Blog Post	Describes daily and season total snow measurements taken from Jackson Hole Mountain Resort snow study plots using a sonar sensor and manual measurements.
Virtual Snow Stakes: A New Method for Snow Depth Measurement at Remote Camera Stations (2023)	Journal	Develops a method to superimpose virtual measurement devices onto images to facilitate camera-based snow depth observations without additional equipment installation.
Long-Term Monitoring of the Sierra Nevada Snowpack Using Wireless Sensor Networks (2022)	Journal	Provides details of 13 low-power wireless Internet of Things networks throughout the American River basin to monitor California's snowpack, which include 945 environmental sensors. Discusses the challenges associated with large-scale environmental monitoring in extreme conditions.
How Do You Measure Snow in the Remote Mountain West? Use a Snow Pillow, of Course (2021)	The Weather Channel	Describes snow depth measurement in remote mountainous locations of the western United States from 800 stations in the Snow Telemetry (SNOTEL) Network, including snow pillow measurements of the weight of the water in the snowpack.
Spatially Extensive Ground-Penetrating Radar Snow Depth Observations During NASA's 2017 SnowEx Campaign: Comparison with In-Situ, Airborne and Satellite Observations (2019)	Journal	Collects approximately 1.3 million ground-penetrating radar snow depth and SWE observations to assess various remote sensing and modeling approaches and compares data with manual snow probe measurements and two other independent estimates of snow depth.

Table ES5. International Research and Resources

Publication or Resource (Year)	Country	Excerpt from Abstract or Description of Resource
A Machine Learning Approach for Estimating Snow Depth Across the European Alps from Sentinel-1 Imagery (2024)	Belgium	Describes a machine learning approach to enhance synthetic aperture radar (SAR)-based snow depth estimation over the European Alps, integrating Sentinel-1 SAR imagery, optical snow cover observations, and topographic, forest cover and snow class information, to accurately estimate snow depth at independent in-situ measurement sites.
Automated Snow Weather Stations (2025)	Canada	Describes snow depth measurement using an acoustic distance sensor, data logger and transmission to the government database.
What Is an Automatic Snow Weather Station (ASWS)? (2016)	Canada	Provides additional detail to source described above regarding snow depth sensors installed at snow pillow sites.
Measurement of the Physical Properties of the Snowpack (2015)	Canada	Compares various snow depth measurement instruments, including portable depth rods and rulers, snow tubes, snow pit observations, pressure and load sensors, radar, GPS and laser-ranging devices, and optical property measurement devices.
Advances in Image-Based Estimation of Snow Variable: A Systematic Literature Review on Recent Studies (2025)	Finland	Provides an overview of current research on the application of image-based techniques for snow cover and snow depth estimation, including identifying key trends, methodologies, challenges and knowledge gaps in the specific area of snow-related hydrological parameters.
Snow Depth Time Series Retrieval by Time-Lapse Photography: Finnish and Italian Case Studies (2021)	Finland	Describes the Finnish Meteorological Institute Image Processing Toolbox used for the retrieval of snow depth in general and snow depth time series specifically, including high temporal resolution, high accuracy, reliable, low-cost solutions that can be easily extended in remote and dangerous areas.
Fully Automated Snow Depth Measurements from Time-Lapse Images Applying a Convolutional Neural Network (2019)	Germany	Investigates automated processing methods to extract snow depth time series using a convolutional neural network.
Testing Unmanned Aircraft for Roadside Snow Avalanche Monitoring (2019)	Norway	Evaluates unmanned aircraft systems (UASs) for capacity to support avalanche program. Testing included assessing if sensors and cameras carried on UASs could provide usable snow depth data, layering and surface information.
Direct Photogrammetry with Multispectral Imagery for UAV-Based Snow Depth Estimation (2022)	Sweden	Explores unmanned aerial vehicle-based multispectral photogrammetry using automatic processing routines to provide continuous spatial snow depth representations in an efficient, affordable and repeatable way.

Publication or Resource (Year)	Country	Excerpt from Abstract or Description of Resource
Monitoring Snow Depth Variations in an Avalanche Release Area Using Low-Cost LiDAR and Optical Sensors (2025)	Switzerland	Develops a monitoring system using low-cost LiDAR and optical sensors to measure small-scale snow depth distribution changes in near real time.
Intercomparison of Photogrammetric Platforms for Spatially Continuous Snow Depth Mapping (2021)	Switzerland	Tests industry-standard photogrammetric platforms, including high-resolution satellite (Pléiades), airplane (Ultracam Eagle M3), unmanned aerial system (eBee+ RTK with SenseFly S.O.D.A. camera) and terrestrial (single lens reflex camera, Canon EOS 750D) platforms, for snow depth mapping in the alpine Dischma valley.

Table ES6. Commercial Products

Product	Vendor	Excerpt from Vendor's Website
LX-80S Snow Depth Sensor	Geolux	Uses advanced 80 GHz radar technology to provide precise contactless measurement of snow level from above. Provides for continuous monitoring of snowpack buildup and melting and requires minimum maintenance.
RK400-14 Customized Laser Snow Depth Sensor	Hunan Rika Electronic Tech Co., Ltd.	Applies the optical triangulation method. Reflected light is collected by the lens and projected onto the CMOS array; the signal processor calculates the position of the light spot on the array through the trigonometric function to obtain the distance to the object.
RK400-14 Laser Snow Depth Sensor	Hunan Rika Electronic Tech Co., Ltd.	See description above.
SNOdar Snow Depth Sensor (Model 54000)	R.M. Young Co.	Uses high-precision LiDAR technology to provide accurate snow depth measurements. Creates detailed, real-time snow depth data, ensuring reliable and efficient snow monitoring for a variety of applications.

Detailed Findings

Background

Roadways through mountainous regions of California have locations with historical collection points that require measurement of snow accumulation, snow depth and snowmelt activity. California Department of Transportation (Caltrans) staff members measure the snow depth in these locations every day from November through May. Snow depth routinely reaches 20 feet and may be more in some locations.

Caltrans staff collecting snow depth data also describe roadway and weather conditions at the measurement location and whether chains are required to reach the measurement site. Data from monitoring locations is collected, documented and forwarded to Caltrans headquarters for long-term retention in a database. Many allied agencies, including the National Weather Service, use this information for monitoring climate changes, forecasting and other applications.

Currently, measurements are manually recorded using line of sight to a snow stake. Staffing challenges, people engaging in recreational activities and limited line-of-sight access make it difficult for Caltrans staff to record timely readings in more remote locations. Given the need to ensure safety for the public and Caltrans maintenance crews gathering the data, Caltrans District 3 is interested in learning more about remote snow depth monitoring practices that have the potential to replace current manual measurements.

This Preliminary Investigation sought information in a range of topic areas:

- Research or agency experience that compares manual snow stake readings with automated or remote readings.
- Best practices for remote monitoring of snow depth.
- Types and reliability of power sources used in extremely remote locations.
- Time-tested commercial sensors and monitors.

Information for this investigation was gathered through a survey of state departments of transportation (DOTs), Caltrans districts and other public institutions that examined experiences with remote snow depth monitoring. A literature search that sought relevant in-progress and completed domestic and international research and related resources supplemented survey findings.

Survey of Practice

An online survey that sought information about automated, remote snow depth data collection practices and equipment, manual measurements and power needs was distributed to three respondent groups:

- State DOT members of the Clear Roads pooled fund study.
- Selected Caltrans districts.
- Other public agencies and institutions expected to have experience with remote snow depth measurement.

Survey questions are provided in Appendix A.

The survey received 23 responses, including 16 state transportation agencies, three Caltrans districts and four other public institutions:

State Transportation Agencies

- Arizona DOT
- Connecticut DOT
- Idaho Transportation Department
- Iowa DOT
- Kentucky Transportation Cabinet
- Massachusetts DOT
- Michigan DOT
- Montana DOT
- Nebraska DOT
- New York State DOT
- North Dakota DOT
- Oregon DOT
- Pennsylvania DOT
- South Dakota DOT
- Texas DOT
- Virginia DOT

Caltrans

- District 2
- District 6
- District 9

Other Public Institutions

- California Department of Water Resources (CDWR)
- National Center for Atmospheric Research (NCAR), National Science Foundation
- Natural Resources Conservation Service (NRCS), U.S. Department of Agriculture
- University of Washington (UW)

The survey received two responses from CDWR:

- Snow Surveys and Water Supply Forecasting Unit (*Snow Surveys*)
- Hydrology Section (*Hydrology*)

All responding state transportation agencies and Caltrans districts do not remotely gather snow depth measurements in the manner envisioned by Caltrans. Five respondents from the four other public institutions responding to the survey described remote tools and practices to collect and monitor snow depth data.

Survey findings are presented below in two categories:

- Respondents' snow monitoring practices.
- Respondents not remotely measuring snow depth.

Respondents' Snow Monitoring Practices

Survey responses from the five respondents describing snow measurement practices are summarized below in four topic areas:

- General snow depth measurement practices.
- Managing snow depth measurement systems.
- Measurement tools and vendors.
- Assessment and recommendations.

General Snow Depth Measurement Practices

Respondents provided information about what, how, where and when snow depth is measured and monitored in these topic areas:

- Monitoring program history.
- Snow parameters measured.
- Remote snow depth measurement.
- Manual snow depth measurement.

Monitoring Program History

NRCS began remote snow depth monitoring in the 1970s. After launching remote snow measurement in the 1970s and 1980s, CDWR is "systematically modernizing and standardizing monitoring stations for easier maintenance and upkeep."

The NRCS region encompassing Oregon, Washington and Northern California collected snow depth data manually before installation of its first automated stations. Currently, the region is upgrading to better-performing monitoring equipment (see Table 2 and section on Measurement Tools and Vendors). Any new stations are Snolite sites — aerial markers measuring snowpack but not cumulative precipitation or snow water equivalent (SWE) — which can be relatively easily deployed without National Environmental Policy Act (NEPA) regulatory requirements.

The NRCS website comments on the agency's water and climate collection and stewardship:

> Since the early days of the snow survey program, aerial markers have been used to measure snowpack in very remote areas where accessibility is limited.
>
> In the last few years, some aerial markers have been outfitted with basic sensors, such as temperature and snow depth, and telemetered using the Iridium Satellite System. Aerial markers with these sensors are called Snolite sites.

NCAR began remote measuring practices in 2007. UW has employed snow depth monitoring in academic research since 2013; however, the protocol for each field experiment changes based on the goals of the research project.

Snow Parameters Measured

Snow depth is the primary measurement of interest in this investigation and respondents reported a wide range of automated measurement capabilities. While the UW respondent noted that snow depth measurements depended on the height of the sensor, other respondents identified specific measurement depths:

- Ten feet up to 15 feet, depending on the height of the sensor placement (*NCAR*).
- Between 20 feet (*CDWR/Snow Surveys*) and 30 feet (*CDWR/Hydrology*).
- Determined by sensor limits; maximum recorded was 235 feet (*NRCS*).

Respondents from NCAR and UW do not measure snow quality, and the CDWR/Hydrology respondent noted that snow quality could refer to:

- Snow purity
- Pollutant or microplastic deposition (for example, deposited from the sky)
- Liquid water equivalent runoff and resulting snow consolidation or layering and when it reaches an isothermal stage

Other parameters of interest reported by respondents, described below, include water content variables, and the weather and other environmental parameters measured, such as soil characteristics and solar radiation.

Water Content Variables

Respondents reported measuring snow water content (*CDWR/Hydrology* and *Snow Surveys*) or more specific water content variables:

- *NCAR.* Measures liquid water equivalent (LWE) and SWE. SWE is measured with a combination of LWE and snow depth sensors.
- *NRCS*. Measures SWE using a fluid-filled snow pillow and at Snow Telemetry (SNOTEL) Network stations (Figure 1), a snow telemetry system designed to collect snowpack and related climatic data across the Western U.S.

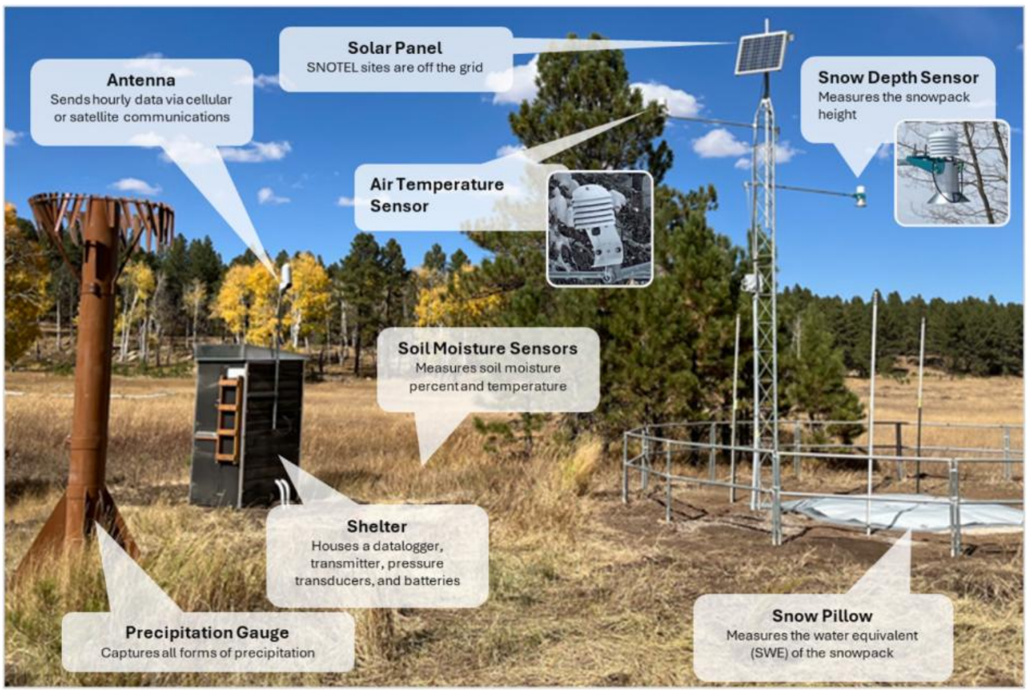

Figure 1. SNOTEL Station Components

(*Source*: Natural Resources Conservation Service.)

Related Resource

What is a SNOTEL Station? Natural Resources Conservation Service, U.S. Department of Agriculture, undated.
https://www.nrcs.usda.gov/state-offices/nevada/what-is-a-snotel-station#:~:text=The%20Natural%20Resources%20Conservation%20Service,the%20Western%20U.S.%20and%20Alaska
From the website: SNOTEL provides a reliable, cost-effective way to collect snowpack and other climate data needed to produce water supply forecasts and support resource management across the West. Whether used during normal conditions, to mitigate droughts or to predict flooding, SNOTEL is essential to water management. A standard SNOTEL site measures and records hourly data on snow depth, snow

water equivalent, precipitation, air temperature, soil moisture and soil temperature. These data are free and available to the public.

Weather and Other Environmental Parameters Measured

Responding agencies measure weather and other environmental parameters such as soil characteristics and solar radiation. Survey responses are summarized in Table 1.

Table 1. Weather and Environmental Parameters Measured

Parameter	Agency and Comments
Precipitation	*CDWR/Hydrology*. Rain/snow/sleet. *NRCS*. Cumulative precipitation.
Soil Characteristics	*NRCS.* Soil moisture and temperature are measured at select sites.
Solar Radiation	*CDWR/Hydrology.* • Incoming radiation (how much energy is sent by the sun). • Outgoing radiation (how much energy is reflecting off the snowpack). • Albedo — the difference between incoming and outgoing to understand energy absorbed and calculate melt/runoff. *NRCS*. Net radiation.
Temperature and Relative Humidity	*CDWR/Hydrology.* *NRCS.* Above-ground temperature profiles and relative humidity recorded at some stations. *UW*. Snow surface temperature.
Weather Characteristics	*UW.*

Remote Snow Depth Measurement

Respondents identified the various tools, including sensors, data loggers, gauges and cameras, their organizations use to remotely measure snow depth and described other parameters associated with the scope of measurement.

NOTE: Measurement tools are described in more detail in the Measurement Tools and Vendors section of this report.

Measurement timing ranged from continuous to hourly and measurement frequency from every five minutes to hourly. The number of collection sites identified the extent of network coverage. Survey responses are summarized in Table 2.

Table 2. Remote Snow Depth Measurement

Agency	Measurement Tools	Timing of Measurement	Frequency of Data Collection	Number of Collection Sites
California Department of Water Resources (*Hydrology*)	• Campbell Scientific SHM31 laser snow depth sensors • Judd snow depth sensors (started upgrading to Geonor sensors; see **Related Resources** below) • Campbell Scientific data loggers • Remote monitoring system designed, built and coded in- house	Measurements taken every 15 minutes	Hourly	70 across the state
California Department of Water Resources (*Snow Surveys*)	Campbell Scientific DCPs, Judd snow depth sensors, SnowFox depth sensors	Continuous during snow accumulation periods (fall/winter/spring)	15-minute or hourly data reading/collection attempted throughout the day	135 (estimated)
National Center for Atmospheric Research	• Snow depth measurements: ○ Laser and acoustic sensors ○ Campbell Scientific ○ Data loggers CR800, 1000, 1000x, 6 • LWE measured with precipitation gauges and sensors such as Geonors, Pluvios and Hotplates • SWE measured with a combination of LWE and snow depth sensors	One observation per minute; time-of-day based on previous research	Once every 5 minutes if a cell modem is connected; otherwise, usually once or twice a winter	Typically, 1 to 5, depending on field programs.
Natural Resources Conservation Service	• Snow depth measurements: ○ Judd acoustic depth sensor ○ Transitioning to Sommer USH-9 • SWE measured with fluid-filled snow pillow.	Measurements collected hourly based on needs and power usage	Hourly	Over 160 automated stations in the region
University of Washington	• Campbell Scientific acoustic snow depth sensor used at Snoqualmie Pass in conjunction with Washington State DOT • Time-lapse cameras (varied manufacturers) and poles in many remote locations	Hourly	Hourly	Varies

The UW respondent noted that different snow depth measurement practices are used depending on the research project. For example, a recent project exploring snow sublimation (evaporation rather than melting) used LiDAR from self-driving cars to map spatial fields of snow depth and tracked blowing snow and moving dunes (see **Related Resources** below).

Related Resources

"**Sublimation of Snow**," Jessica Lundquist, Julie Vano, Ethan Gutmann, Daniel Hogan, Eli Schwat, Michael Haugeneder, Emilio Mateo, Steve Oncley, Chris Roden, Elise Osenga and Liz Carver, *Bulletin of the American Meteorological Society*, Vol. 105, Issue 6, pages E975-E990, 2024.
https://journals.ametsoc.org/view/journals/bams/105/6/BAMS-D-23-0191.1.xml?tab_body=fulltext-display
From the abstract: Snow is a vital part of water resources, and sublimation may remove 10%–90% of snowfall from the system. To improve our understanding of the physics that govern sublimation rates, as well as how those rates might change with the climate, we deployed an array of four towers with over 100 instruments from NCAR's Integrated Surface Flux System from November 2022 to June 2023 in the East River watershed, Colorado, in conjunction with the U.S. Department of Energy's Surface Atmosphere Integrated Field Laboratory (SAIL) and the National Oceanic and Atmospheric Administration (NOAA)'s Study of Precipitation, the Lower Atmosphere and Surface for Hydrometeorology (SPLASH) campaigns. Mass balance observations, snow pits, particle flux sensors, and terrestrial lidar scans of the evolving snowfield demonstrated how blowing snow influences sublimation rates, which we quantified with latent heat fluxes measured by eddy-covariance systems at heights 1–20 m above the snow surface. Detailed temperature profiles at finer resolutions highlighted the role of the stable boundary layer. Four-stream radiometers indicated the important role of changing albedo in the energy balance and its relationship to water vapor losses. Collectively, these observations span scales from seconds to seasons, from boundary layer turbulence to valley circulation to mesoscale meteorology. We describe the field campaign, highlights in the observations, and outreach and education products we are creating to facilitate cross-disciplinary dialogue and convey relevant findings to those seeking to better understand Colorado River snow and streamflow.

Hydrology Data Acquisition System (HyDAS), Bryan Prestel, *Western States Rural Transportation Technology Implementers Forum*, 2018.
https://www.westernstatesforum.org/Documents/2018/Presentations/CaDWR_Prestel_FINALb_DWRHyDAS.pdf
This presentation from one of the CDWR survey respondents describes the snow depth sensors and other instruments and equipment CDWR uses to operate, maintain and calibrate 139 real-time remote Hydrology Data Acquisition Systems in the Sierra Nevada, North Coast, San Francisco Bay Area and Central Coast. A discussion of pros and cons of the Judd sonic depth sensor and SHM-XX laser depth sensor begins on slide 50; slide 53 describes the SHM-30.

Snow Survey and Water Supply Forecasting Program, Natural Resources Conservation Service, U.S. Department of Agriculture, undated.
https://www.nrcs.usda.gov/programs-initiatives/sswsf-snow-survey-and-water-supply-forecasting-program
From the website: NRCS hydrologists manage a comprehensive network of manually-measured snow courses and automated Snow Telemetry (SNOTEL) monitoring sites throughout the West, manage the data collection process, and estimate the runoff that will occur when it melts.

Manual Snow Depth Measurement

In addition to remote or automatic measurement systems, responding institutions reported on manual snow depth measurement methods and how co-located manual and remote measurements compare. Brief respondent comments on manual measurement methods are followed by information describing the comparative accuracy of manual and remote snow depth measurements.

Manual Measurement Methods

Respondents identified these methods for manual snow depth measurement:

- Avalanche probes (*UW*).
- Federal samplers (*CDWR/Hydrology* and *Snow Surveys;* and *UW*). The CDWR/Hydrology respondent noted that the samplers were developed by James Church in the early 1900s and described the instrument as three-foot tube sections that are screwed together with a cutter head on the base that cores the snow, measuring its weight and depth.
- Snow courses (permanent observation sites) and aerial markers or pipes with cross members that are visible from a flyover (*NRCS*).

CDWR's website addresses the data collection methods used in California's Cooperative Snow Surveys. The Data Collection web page describes generally how data is collected, and a Snow Survey Procedure Manual includes sections on snow survey equipment and a step-by-step guide to conducting a snow survey.

Comparing Manual and Remote Measurements

Manual snow depth measurements can be used to verify the accuracy of automated or remote measurements (see the Managing Snow Depth Measurement Systems section of this report for further details). When queried about the accuracy of remote measurements as compared to manual measurements, the UW respondent reported that they were "similar," while the CDWR/Snow Surveys respondent said that the comparison varies — some co-located measurements are the same while others differ.

Two respondents provided an error range comparing manual and automated measurements:

- Between 0% and 20%, depending on the area and the depth of the snowpack, density and compression within the tube itself as it is pushed down and compacts the snow (*CDWR/Hydrology*).
- Equal or less than 10% between "ground truth" or manual measurement at a site where sensor data is available, assuming snowpack is fairly uniform across the site and there are no other onsite issues (*NRCS*).

The NCAR respondent recognized that accuracy must be measured in the immediate vicinity of the automated measurements, and it can be challenging to avoid disturbing the snow around the sensor. While estimates can illustrate that automated sensor measurements are in the "ballpark," the respondent noted unspecified issues that cause uncertainty in the accuracy of either method.

Related Resources

History of Snow Surveying, California Cooperative Snow Surveys, California Department of Water Resources, 2024.
https://cdec.water.ca.gov/snow/info/HistSnowSurvey.html
This website describes the history of the Cooperative Snow Surveys Program, established by the California State Legislature in 1929. *From the website:*

> Today in California more than 50 state, national, and private agencies pool their efforts in collecting snow data. Over three hundred snow courses are sampled each winter with some of the original courses, established more than 60 years ago by Dr. Church, still in use.

Manual Snow Measurements, Natural Resources Conservation Service, U.S. Department of Agriculture, undated.
https://www.nrcs.usda.gov/resources/education-and-teaching-materials/water-and-climate-data-collection-and-stewardship
From the website: Snow courses are locations where manual snow measurements are taken during the winter season to determine the depth and water content of the snowpack. Snow courses are permanent locations and represent the snowpack conditions at a given elevation in a given area.
….

Aerial markers are used to measure the depth of snow. Surveyors then use an estimated density to calculate snow water equivalent. The markers are located in remote locations that are difficult to reach by over-snow travel. They consist of one measuring point marked by a pipe with cross members that can be easily observed by aircraft flyover.

Technical Documentation: Snowpack, U.S. Environmental Protection Agency, 2016.
https://www.epa.gov/sites/default/files/2016-08/documents/snowpack_documentation.pdf
This technical documentation describes changes in springtime mountain snowpack over time and includes sections on data sources and snowpack measurement methodology. *From the document*:

> The NRCS SNOTEL network now operates more than 800 remote sites in the western United States, including Alaska. In contrast to monthly manual snow course measurements, SNOTEL sensor data are recorded every 15 minutes and reported daily to two master stations. In most cases, a SNOTEL site was located near a snow course, and after a period of overlap to establish statistical relationships, the co-located manual snow course measurements were discontinued. Hundreds of other manual snow course sites are still in use, however, and data from these sites are used to augment data from the SNOTEL network and provide more complete coverage of conditions throughout the western United States. Basic information on the SNOTEL network can be found at: www.wcc.nrcs.usda.gov/snotel/SNOTEL_brochure.pdf.
>
> Additional snowpack data come from observations made by the California Department of Water Resources.

Federal Snow Sampling Tubes, Performance Results Plus, Inc., 2025.
https://prph2o.com/federal-snow-sampling-tubes-1/
From the website: The Mt. Rose or "Federal" type sampler is a professional grade snow sampler based on USFS [U.S. Forest Service] design criteria. This set measures snow depth and water content to determine snow density. Sensitive spring balance is graduated in both equivalent inches and centimeters of water. The sampler is made with Cutter I.D. of 1.554in and 1.625in (4.13 cm) I.D. anodized aluminum material.

The sampler can be specified in English or metric units with the standard USFS length in 31" long sections and the metric in 80 centimeter sections. The tubes are precision machined to a very specific volume for accurate water equivalent measurements. The standard sets can be ordered with up to eight sections. The standard Federal cutter is a 16 tooth weighing 3 oz. and is typically used for sampling up to 30 feet deep.

Managing Snow Depth Measurement Systems

The responding public institutions provided insight into considerations inherent in remote snow depth data collection and management:

- Power sources and outages.
- System downtime or failure.
- Managing snow depth data.
- Data accuracy and verification.

Solar panels and batteries power all remote snow depth measurement systems identified by respondents. Power outages at remote snow depth monitoring stations can happen for a variety of reasons, such as snow covering solar panels. Agency responses are summarized below.

California Department of Water Resources/Hydrology

Topic	Description
Power Sources	The off-grid systems use 20- to 30-watt solar panels, with battery capacity of 55 to 200 ampere-hours, depending on available space in the electrical enclosure.
Power Outages	Potential causes of power outages include: • Water intrusion • Bear damage • Avalanche damage • Solar regulator failing • Old batteries • Devices with heaters that should have been disabled
System Downtime	Unquantifiable, but reasons vary between common and unique based on geographic location and environmental phenomenon.
Data Management	Raw snow depth data collected through the Geostationary Operational Environmental Satellites (GOES) system and managed by numerous groups for quality assurance and quality control.
Data Accuracy and Verification	Remote data is verified through the Airborne Snow Observatory and nearby monthly manual measurements. Understanding average error percentage is important due to variable and undulating terrain.

California Department of Water Resources/Snow Surveys

Topic	Description
Power Sources	Solar-charged batteries power sensors and data collection platforms.
Power Outages	Snow-covered panels can drop the battery charge and prevent data transmission to GOES.
System Downtime	Monitoring site downtime varies from a few days to a week. If the station fails overall, it would be out of commission for the remainder of the season.

Topic	Description
Data Management	Data collection platforms store and periodically transmit data to the California Data Exchange Center.
Data Accuracy and Verification	Monthly manual snow surveys at many automated snow sensors support calibration during the winter months.

National Center for Atmospheric Research

Topic	Description
Power Sources	• Acoustic sensors in remote systems use one or two solar-charged 12-volt batteries. • Laser sensors usually only operate on AC power.
Power Outages	Power outages caused by snow-covered solar panels have only occurred a few times late in the winter season.
System Downtime	Monitoring site downtime is minimal.
Data Management	Data stored on a local server is uploaded into a MySQL server enabling distribution of the data.
Data Accuracy and Verification	Webcams pointing at rulers and manual stakes can verify remote measurements.

Natural Resources Conservation Service

Topic	Description
Power Sources	Automated stations operate on solar power.
Power Outages	Minimal (0 to 1 annually) power outages happened more frequently when a meteor burst radio telemetry system was used to transmit data, prior to those systems' retirements. Low power, however, could cause a remote monitoring site to go down.
System Downtime	While average downtime is unknown, reasons could include site damage, telemetry outage or weather.
Data Management	Data is transmitted through GOES, iridium satellite network or cell network to an internal database where trained data managers oversee it daily in winter and less frequently during the summer.
Data Accuracy and Verification	Snow depth sensor height is measured to ensure accurate offsets in database; some sites are ground-truthed during the winter. Comparisons to period of record also help to determine if current data is reasonable.

University of Washington

Topic	Description
Power Sources	Solar panels power data loggers and batteries for time lapse cameras.
Power Outages	Outages occur; no details provided.
System Downtime	Monitoring site downtime varies substantially.
Data Management	Data management varies by research project. Data is archived at either NASA, Department of Energy or UW.
Data Accuracy and Verification	Camera images of acoustic or LiDAR snow depth sensors provide evidence of what is causing sensor errors.

Related Resources

GOES Satellite Network, National Aeronautics and Space Administration, 2025.
https://science.nasa.gov/mission/goes/
From the website: Geostationary Operational Environmental Satellites (GOES) is a collaborative NOAA [National Oceanic and Atmospheric Administration] and NASA [National Aeronautics and Space Administration] program providing continuous imagery and data on atmospheric conditions and solar activity (space weather). NASA builds and launches the GOES and NOAA operates them.

Welcome to California Data Exchange Center, California Department of Water Resources, 2024.
https://cdec.water.ca.gov/
From the website: [The] CDEC provides users access to hydrologic and climate information used to support real-time flood management and water supply needs in California.

Airborne Snow Observatory, NASA Jet Propulsion Laboratory, California Institute of Technology, National Aeronautics and Space Administration, undated.
https://www.jpl.nasa.gov/missions/airborne-snow-observatory-aso/
From the website: The Airborne Snow Observatory is an Earth-based mission designed to collect data on the snow melt flowing out of major water basins in the western United States. The data could help improve water management for 1.5 billion people worldwide who rely on snow melt for their water supply.

Measurement Tools and Vendors

Survey respondents identified the equipment their institutions use to remotely measure and monitor snow depth. Table 2 (see page 21) provides respondents' descriptions of the measurement tools used, including these vendors:

- Campbell Scientific, Inc.
- Geonor, Inc.
- Hydroinnova, LLC
- Judd Communications, LLC
- Sommer Messtechnik

The UW respondent also reported using time-lapse cameras from varied manufacturers.

In many cases, respondents did not specify model numbers or other details. Both the equipment models identified by respondents and a sampling of other products from these vendors are described in more detail below.

Campbell Scientific

Four of the five respondents use Campbell Scientific products for remote snow depth measurement:

- *CDWR/Hydrology*: Data loggers, including CR1000 (retired per vendor's website), CR1000x (retired per vendor's website) and CR1000xe.
- *CDWR/Snow Surveys*: Data collection platform (DCP) (vendor's website indicates these are no longer available).
- *NCAR*: Unspecified laser and acoustic sensors and data loggers, including CR800, CR1000 and CR1000x (all three models are retired per vendor's website).
- *UW*: Acoustic snow depth sensor, model unspecified.

Snow Depth Sensors

Table 3 highlights Campbell Scientific's ultrasonic, laser- and acoustic-based snow depth sensors. The vendor also offers distance sensors that are used to determine snow depth.

Table 3. Campbell Scientific Snow Depth Sensors

Product/Description	Measurement Range	Resolution	Accuracy	Operating Temperature Range	Power Supply and Consumption
SnowVue 10 Digital Snow-Depth Sensor Ultrasonic snow-depth sensor (Figure 2)	0.4 to 10 m (1.3 to 32.8 ft) distance from sensor	0.1 mm	0.2% of distance to target, based on uniform air temperature between sensor and flat, solid target. Requires external temperature compensation.	-45°C to +50°C	*Supply*: 9 to 18 VDC *Consumption*: • 210 mA (peak) • 14 mA (average at 20°C)
SDMS40 Multipoint Scanning Snowfall Sensor Laser-based snowfall sensor	< 10 m (< 32.8 ft)	1 mm	±3 mm	-40°C to +50°C	*Supply*: 12 to 15 VDC, 2 A *Consumption*: • 250 mA (active) • 1300 mA (with heater)
SR50A-EE-L Anodized Sonic Distance Sensor for Extreme Environments Acoustic-based snow-depth sensor	0.5 to 10 m (1.6 to 32.8 ft)	0.25 mm (0.01 in.)	±1 cm (0.4 in.) or 0.4% of distance to target (whichever is greatest). Requires external temperature compensation.	-45°C to +50°C	*Supply*: 9 to 18 VDC (typically powered by data logger's 12 VDC power supply) *Consumption*: 250 mA (typical)

Product/Description	Measurement Range	Resolution	Accuracy	Operating Temperature Range	Power Supply and Consumption
CS725 Snow Water Equivalent Sensor SWE measurement through electromagnetic energy (Figure 3)	600 mm maximum water equivalent	1 mm	±15 mm (from 0 to 300 mm) ±15% (from 300 to 600 mm)	-40°C to +40°C	*Supply*: 11 to 15 VDC *Consumption*: 180 mA
SR50AT-L Sonic Distance Sensor with Temperature Sensor Acoustic distance sensor determines snow depth (Figure 4)	0.5 to 10 m (1.6 to 32.8 ft)	0.25 mm (0.01 in.)	±1 cm (0.4 in.) or 0.4% of distance to target (whichever is greatest).	-45°C to +50°C	*Supply*: 9 to 18 VDC (typically powered by data logger's 12 VDC power supply) *Consumption*: 250 mA (typical)
SR50AH-L Heated Sonic Distance Sensor Heated sonic distance sensor determines snow depth	0.5 to 10 m (1.6 to 32.8 ft)	0.25 mm (0.01 in.)	±1 cm (0.4 in.) or 0.4% of distance to target (whichever is greatest). Requires external temperature compensation.	-45°C to +50°C	*Supply*: 9 to 18 VDC (typically powered by data logger's 12 VDC power supply) *Consumption*: Not provided
SR50ATH-L Sonic Distance Sensor with Heater and Temperature Sensor Heated sonic distance sensor with integrated external temperature probe and heater	0.5 to 10 m (1.6 to 32.8 ft)	0.25 mm (0.01 in.)	±1 cm (0.4 in.) or 0.4% of distance to target (whichever is greatest).	-45°C to +50°C	*Supply*: 9 to 18 VDC (typically powered by data logger's 12 VDC power supply) *Consumption*: 250 mA (typical without heater)

Figure 2. SnowVue 10 Sensor
(*Source*: Campbell Scientific, Inc.)

Figure 3. CS725 SWE Sensor
(*Source*: Campbell Scientific, Inc.)

Figure 4. SR50AT-L Sonic Distance Sensor
(*Source*: Campbell Scientific, Inc.)

Data Loggers

Campbell Scientific's Data Loggers web page describes data loggers as:

> [A]n essential component in data acquisition systems. They can scan a wide variety of measurement sensors, perform any programmed calculations, convert the data to other units of measurement, and store the data in memory. Data loggers can also transmit the data for analysis, sharing and reporting, as well as control external devices.

While other Campbell Scientific data loggers are available, the current model used by CDWR/Hydrology — and identified by the company as its flagship model — is the CR1000Xe Measurement and Control Datalogger. *From the manufacturer's description*:

> The CR1000Xe provides measurement and control for a wide variety of applications. Its reliability and ruggedness make it an excellent choice for remote environmental applications.
>
> ….
>
> The CR1000Xe is a low-powered device that measures analog and digital sensors, processes and stores measurements, and adapts to any communications link. It stores data and programs in non-volatile flash memory. The onboard programming language — common to all Campbell Scientific data loggers — allows users to create solutions perfectly tailored to the application.

The website includes a fact sheet, specifications and other manuals and technical papers on the device.

Related Resource

Ultrasonic Depth Sensor, Judd Communications, LLC, 2023.
http://juddcom.com/
From the website: The sensor works by measuring the time required for an ultrasonic pulse to travel to and from a target surface. An integrated temperature probe with solar radiation shield, provides an air temperature measurement for properly compensating the distance measured. An embedded microcontroller calculates a temperature compensated distance and performs an error checking routine.

Geonor, Inc.

The CDWR/Hydrology respondent reported upgrading from Judd snow depth sensors to the SHM31 laser snow depth sensor, noting that it can "detect 1mm of snow, the thickness of a business card [and] you can easily integrate [it] into your RWIS [road weather information system]." The NCAR respondent also reported using an unspecified Geonor gauge or sensor to measure LWE. The SHM31 snow sensor is described below.

Lufft Snow Depth Sensor SHM31

Topic	Description
Measurement Range	0 – 15 meters
Resolution	• Repeatability: 0.6 mm • Intermediate precision/reproducibility: 5 mm
Accuracy	+/- 5 mm + 0.06%
Operating Temperature Range	-45°C to +50°C

Topic	Description
Power Supply	12, 24 VDC
Power Consumption	• Without heater: approximately 0.7 W • With window heating: approximately 3.4 W
Data Sheet	https://irp.cdn-website.com/05996b94/files/uploaded/Lufft_Snow_Depth_Sensor_SHM31.pdf

Related Resource

SHM31 Snow Depth Sensor, Geonor, Inc., 2025.
https://www.geonor.com/laser-snow-depth-sensor-30/31
The website describes how the new Lufft SHM31 snow height sensor differs from the Lufft SHM30, which still operates in many networks. Primary differences of the Lufft SHM31 compared to the Lufft SHM30 include:

- Sensor performance is increased in extreme weather conditions due to the extended heating function and new laser diode design.
- New features decrease energy use in low-current idle operation.
- Distances of up to 30 meters to natural, diffuse reflective surfaces are precisely measured with the opto-electronic laser distance sensor and visible, easy-to-measure measuring beam.
- Snow depth up to 15 meters is measured within seconds, millimeter-accurate and reliable. The signal intensity provides ground-snow detection.
- The optical measuring method is independent of temperature fluctuations and temporary impairments of the measuring process, such as resulting from precipitation, are compensated by the operating mode.
- A robust housing and an elaborate operation principle require almost no maintenance over the lifetime of the sensor.

Hydroinnova

The CDWR/Snow Survey respondent reported use of a SnowFox depth sensor. The product is described in the **Related Resource** below; no other technical details are available on the vendor's website.

Related Resource

Snow Pack, Hydroinnova, 2011.
https://hydroinnova.com/snow_water.html
From the website:

> The cosmic-ray technique relies on the attenuation of naturally occurring "background" neutrons by the hydrogen contained in water. Because the concentration of hydrogen in water does not change, the technique is not sensitive to the physical state of water.
>
> This makes it ideal for determining the water equivalent depth of snow (SWE). When SWE increases, the natural background neutron intensity goes down.
>
> The technique can be operated *invasively* for small-area averaging in deep snow (download Fact Sheet on our ***SnowFox*** product, 220 KB), or *non-invasively* for wide areal averaging and smaller snow depths (up to ~15 cm SWE).

For non-invasive measurements we recommend our CRS-1000 series probes (go to ***CRS-1000***).

Advantages of the cosmic-ray probe for snow:

- Sensitive to water equivalent depth of snow.
- Capable of averaging over large areas (in non-invasive mode only).
- Easy to transport and install.
- Fluidless (as opposed to snow pillows filled with anti-freeze chemical).
- Can be installed on hillslopes or in thick forests.

Options for data logging and telemetry are the same as for Hydroinnova's CRS-1000 series of soil moisture probes. Our data logger will also support ultrasonic depth sensors and other selected sensors from third-party manufacturers.

Compatibility with selected third-party data logging systems is also available.

Judd Communications, LLC

Both CDWR respondents (*Hydrology* and *Snow Surveys*) use Judd snow depth sensors, though the Hydrology respondent reported upgrading from the Judd to a Geonor sensor. The NRCS respondent is using a Judd acoustic depth sensor but transitioning to the Sommer USH-9. The Judd ultrasonic depth sensor, the only product listed on the vendor's website, is described below.

Judd Ultrasonic Depth Sensor

Topic	Description
Measurement Range	.5 to 10 meters (1.6 to 32.8 feet)
Resolution	3 mm (.12 inches)
Accuracy	• Snow depth: 1 cm or .4 % distance to target • Temperature: 1°C, -40°C to +85°C
Operating Temperature Range	-40°C to + 70°C (-40°F to 158°F)
Power Supply	12 to 24 VDC, 50 mA
Power Consumption	Not provided
Data Sheet	http://juddcom.com/

Related Resource

Ultrasonic Depth Sensor, Judd Communications, LLC, 2023.
http://juddcom.com/
From the website: The sensor works by measuring the time required for an ultrasonic pulse to travel to and from a target surface. An integrated temperature probe with solar radiation shield, provides an air temperature measurement for properly compensating the distance measured. An embedded microcontroller calculates a temperature compensated distance and performs an error checking routine.

Sommer Messtechnik

NRCS is transitioning from a Judd acoustic depth sensor to the Sommer USH-9 ultrasonic level sensor, described in the table and **Related Resources** below. Also described is the Sommer LSH-10 laser snow depth sensor.

Sommer USH-9 Ultrasonic Level Sensor

Topic	Description
Measurement Range	0 to10 m (0 to 32.8 ft)
Resolution	1 mm
Accuracy	max. ± 1 cm; typically 0.1% FS
Operating Temperature Range	-41°C to 60°C (-42°F to 140°F) • Resolution 0.1 °C • Accuracy 0.3 °C
Power Supply	9 to 28 VDC; reverse voltage protection, overvoltage protection
Power Consumption	Active measurement: typically 40 mA (max.300 mA for 0.05 s)
Data Sheet	https://www.sommer.at/en/products/snow-ice/snow-depth-sensor-ush-9/download/324_75e6b8d8f1e61bf4ed6a9ba024f317ed

Sommer LSH-10 Laser Snow Depth Sensor

Topic	Description
Measurement Range	0 to10 m (0 to 32.8 ft)
Resolution	0.1 mm
Accuracy	< +/-3mm
Operating Temperature Range	-40°C to 50°C
Power Supply	9 to 27 VDC
Power Consumption	10 mAh / day (with measuring interval 15 min)
Data Sheet	https://www.sommer.at/en/products/snow-ice/laser-snow-depth-sensor-lsh-10

Related Resources

Snow Depth Sensor USH-9, Sommer Messtechnik, 2023.
https://www.sommer.at/en/products/snow-ice/snow-depth-sensor-ush-9
From the website: The USH-9 is an ultrasonic sensor for the precise, continuous and non-contact recording of snow depths. The robust design, a special ultrasonic head as well as an extremely low energy consumption makes the USH-9 a very suitable system for extreme weather conditions and so for alpine and high alpine terrain.

Features and advantages

- Continuous and non-contact measurement

- Reliable sensor for extreme environmental conditions and high alpine employment
- Robust, sealed and therefore maintenance free ceramic membrane with protective shield against ice and snow
- High level of accuracy thanks to the integrated temperature compensation and filtering of snow and rainfall using intelligent spectrum analysis
- Energy-saving operation through sleep modus, ideal for solar-powered measuring stations

Laser Snow Depth Sensor LSH-10, Sommer Messtechnik, 2023.
https://www.sommer.at/en/products/snow-ice/laser-snow-depth-sensor-lsh-10
From the website: The laser-based snow depth sensor from SOMMER LSH-10 stands for unreached accuracy in measuring snow level. The LSH [uses] millimeter-accuracy to output the very high resolution even over long measurement distances. An optimized heating system used in the LSH enables the sensor to work in all weather conditions without any maintenance. Opto-electronic/laser based rangefinder technology makes sure to provide the best measurement data possible.

Features and advantages

- Continuous and non-contact measurement
- Reliable sensor in extreme conditions
- State-of-the-art laser technology
- Correct measurement in snowfall, difficult reflection conditions
- Integrated lightning protection
- High measurement accuracy
- Energy-saving sensor operation - smart heating control
- Output values: snow depth, distance to surface, echo strength, signal quality, status
- Sensor integration - interfaces: SDI-12, RS-485, 4...20mA, parametrisation via Commander software

Time-Lapse Cameras

The UW respondent reported that time-lapse cameras (Figure 5) provided by a variety of manufacturers are used with poles in many remote locations to monitor snow depth. The cameras, the respondent noted, help with quality control as possible issues with acoustic or LiDAR-based snow depth sensors have been observed.

Figure 5. Installed Time-Lapse Camera

(*Source:* University of Washington, Mountain Hydrology Research.)

The University of Washington's Mountain Hydrology Research Group developed a Guide to Installing Time Lapse Cameras in Trees, which includes required equipment, choosing a site and tree, and installing and setting up the camera. The guide's recommendations for choosing a site:

> [C]onsider the topography of the site first. Make sure to find a flat area with as small of a surrounding slope as possible. Snow is subject to "creep," or downslope movement throughout the winter, which can bend the snow depth poles and cause biases in the depth measurements. Also look around when installing your site; avalanches can move downslope and into the flat area. One other thing to note about the site is that your snow depth poles… should have vibrant-colored tape (e.g. bright orange or hot pink) at a fixed increment to make image processing as easy as possible.

Assessment and Recommendations

Survey respondents provided their perspective on snow depth remote measuring practices in three topic areas:

- Most positive aspects of the remote monitoring system.
- Biggest challenges in using a remote monitoring system.
- Recommendations for managing a remote snow depth monitoring system.

Positive Aspects

Benefits vary depending on the research project at UW. Other respondents identified benefits of remote snow depth monitoring systems:

- *Flexibility*. New instruments on the market can be tested while maintaining and allowing old instruments to function with the program CDWR designed (*Hydrology*).
- *Reliability*. The power system and data collection methods are robust and produce few issues (*NCAR*).
- *Wide network coverage*. The remote snow depth monitoring network in the West is robust and provides standards for individual snow monitoring stations (*NRCS*). Similarly, the network covers a wide area within California and provides a good overall picture of the snow water content and depth (*CDWR/Snow Surveys*).

Biggest Challenges

The remoteness of monitoring stations is a common challenge identified by respondents. For example, the CDWR respondents noted that calibrating, maintaining and addressing station failure can be difficult with limited access, and extremely remote areas are only accessible in summer months and only by horseback due to Wilderness Act restrictions. Similarly, the NRCS respondent noted the logistical challenges involved in winter maintenance visits to remote sites. At UW, challenges vary depending on the research project.

Challenges raised by other respondents:

- *Data transmission* if cellular or hardwired connections are not available (*NCAR*).
- *Equipment* such as a snowcat might be convenient for use in California, but accessing the equipment without compromising readings may be a challenge; access should be simple if monitoring is part of an RWIS site (*CDWR/Hydrology*).
- *Staff resources* when a large number of sites (such as SNOTEL) need to be serviced annually, and additional station visits are need to recharge the precipitation gauges (*NRCS*).

Recommendations

Survey respondents with experience with remote snow-depth monitoring offered advice to other agencies interested in remote monitoring in three topic areas:

- Monitoring site location.
- Parameters to measure.
- Equipment considerations.

Monitoring Site Location

Emphasizing "location, location, location," the NCAR representative noted there are many bad locations for a monitoring station, but not many good ones. The respondent recommended scouting potential locations several times during the winter to account for varying snow depths to find one that is representative of the surroundings without large scours or drifts.

The UW respondent recommended flat ground for a stable tower to hold the monitoring instruments, noting that the "horizontal arm may be bent" in extremely high snow years and more accessible sites are preferable for maintenance purposes. The UW respondent also suggested carefully aligning locations with measurement goals to ensure representativeness of the location, as snow depth varies dramatically in space.

Parameters to Measure

The Snow Surveys representative from CDWR offered that while snow water content is more trackable and provides a more accurate reading of snowpack than snow depth, measuring both is preferable as they function as a cross-check. Additionally, the UW respondent noted that stable measurements in the same location over a long time period can account for deviations from "normal."

Equipment Considerations

Respondents identified several equipment placement, operation and maintenance factors to consider in remote snow depth monitoring:

- Ensure the solar panel tower is tall enough and the sensor is placed high enough to account for above-average snowfall winters (*NCAR*).
- Have the appropriate equipment in place to collect winter data if remote communications are not available (*NCAR*).
- Correctly calculate the power needed and disable the device heaters if line power is not sufficient (*CDWR/Hydrology*).
- Run all cables in conduit to avoid water damage but ensure it is breathable to prevent condensation (*CDWR/Hydrology*).
- Keep operation and maintenance simple and standardized:
  - Use pigtail connector wires on instruments.
  - Make troubleshooting easy.
  - Simplify configuration management by allowing easy addition or removal of instruments in one program instead of multiple programs that can cause confusion (*CDWR/Hydrology*).

Respondents Not Remotely Measuring Snow Depth

Respondents from all 16 state transportation agencies and the three Caltrans districts participating in the survey noted that their agencies do not have experience with automated collection of snow depth data in real time. Below are the agency snow depth monitoring practices described by several of these respondents.

North Dakota DOT relies on the National Weather Service "after the fact" and the Development of Maintenance Decision Support System (MDSS) Pooled Fund Study (TPF-5(347)). This pooled fund study is developing an MDSS that will, in part, "evaluate the reliability of predictions and the effectiveness of applied maintenance treatments for specific road and weather conditions so decision support can be improved." The Texas DOT respondent reported that the agency does not use snow gauges.

The New York State DOT respondent noted that New York "has an extensive MESONET network of weather stations that shows snow depth." Mesonet includes a subnetwork of 20 snowpack monitoring sites. A University of Albany NYS Mesonet publication describes the monitoring system:

> The New York State Mesonet operates a subnetwork of snowpack monitoring stations across select areas of the Adirondacks, Tug Hill and Catskills. These stations specifically measure snow depth and SWE. Snow depth is measured every five minutes, and SWE is estimated over a six-hour period with observations provided up to four times daily.
>
> The SWE sensor estimates the amount of water in a column between the ground and the sensor by detecting gamma rays emitted from two naturally-occurring elements in the soil: potassium and thallium. Water attenuates the signal emitted by each element, and the level of attenuation allows the sensor to estimate the amount of water present in the column. The element providing the best estimate is site-specific, and it will take several years of data to determine which element provides the best estimate at each site.

Other respondent comments are presented below in two topic areas:

- Road weather information systems.
- Manual data gathering methods.

Road Weather Information Systems

Three state transportation agencies reported using RWIS for snow depth measurement (*Arizona, Massachusetts* and *Pennsylvania*). The Pennsylvania respondent noted that snowfall is identified at RWIS stations but the amounts are not totaled.

Manual Data Gathering Methods

Respondents mentioned various manual tools:

- Gathering measurements for manual snow depth reports for daily winter storm logs (*Iowa*).
- Snow stakes (*Caltrans District 6*).
- Visual and physical means (*Caltrans District 9*).

Related Resources

Development of Maintenance Decision Support System, Transportation Pooled Fund TPF-5(347), estimated completion September 30, 2025.
https://pooledfund.org/Details/Study/598
From the study description: Agencies could provide more effective maintenance, and provide it more efficiently, with the help of an automated Maintenance Decision Support System (MDSS) that could: assess current road and weather conditions using observations and reasonable inferences based upon observations; provide time- and location-specific weather forecasts along transportation routes; predict how road conditions would change due to forecast weather and the application of several candidate road maintenance treatments; notify state agencies of approaching conditions and suggest optimal maintenance treatments that can be achieved with resources available to the transportation agencies; and evaluate the reliability of predictions and the effectiveness of applied maintenance treatments for specific road and weather conditions so decision support can be improved.

New York State Mesonet Snow Network Data, NYS Mesonet, University of Albany, undated.
https://nysmesonet.org/documents/NYSM_Readme_Snow.pdf
This publication describes the Mesonet Snow Network including instrumentation, data format, special notes on the data and site information.

Related Research and Resources

Findings from a literature search of publicly available domestic and international in-progress and published research and other resources are presented in five categories:

- National Research and Resources.
- State Research and Resources.
- Other Research and Resources.
- International Research and Resources.
- Commercial Products.

National Research and Resources

USDA LTAR [Long-Term Agroecosystem Research] Common Experiment Measurement: Snow, Joel A. Biederman, Keirith A. Snyder, Kevin J. Cole, Robert W. Malone, Gerald N. Flerchinger, Michael H. Cosh and Claire Baffaut, U.S. Department of Agriculture, November 2024.
https://protocols.io/view/usda-ltar-common-experiment-measurement-snow-dmt946r6.pdf
This protocol describes measuring snow depth, among other parameters, including:

- Equipment
- Manual, semimanual and automated methods
- Site maintenance
- Data processing, quality control and data file formats

From page 4:

> **Snow depth equipment**
> Snow depth can be measured using photographs of fixed snow stakes, manual surveys with handheld depth probes, and/or fixed automated ultrasonic sensors that concurrently measure air temperature (common brands include: Campbell Scientific, Judd Sensors, and Novalynx) with an associated data logger to store the data. For targeted, high-value applications, snow depth can be measured by airborne or terrestrially-based light detection and ranging (lidar).

From page 5:

> **Automated methods**
>
> - Sonic distance sensors measure snow depth by emitting an ultrasonic pulse 50 kHz and measuring the time it takes for the emitted pulse to reach the ground or snow surface and reflect back to the sensor (i.e., return interval).
> - Automated measurements are controlled by a data logger (may be solar-powered) at any desired frequency.
> - With increased snow depth, the pulse has less distance to travel and thus a shorter return interval. Since ultrasonic sound pulses vary with air temperature, an air temperature sensor is usually located within the sensor housing to correct for variations in the speed of sound in air.
> - The emitted pulse is conical, and the dimensions of the circle on the ground surface are determined by sensor height. The conical shape should have a clear view of the ground uninfringed by vegetation, fence posts or other objects.
> - The sonic sensor should be perpendicular to the ground surface or to snowboards (i.e., boards mounted at the soil surface) and be mounted securely so the measurements are unaffected by wind moving the sensor.

- Ultrasonic depth sensors are standard equipment at USDA [U.S. Department of Agriculture] SNOTEL network sites.

Emerging Technologies in Snow Monitoring: Report to Congress, Kenneth Nowak, Lindsay Bearup, Deena Larsen, Donna Garcia, Chad Moore and Sarah Baker, Bureau of Reclamation, U.S. Department of the Interior, November 2021.
https://www.usbr.gov/research/docs/news/Emerging_Snow_Monitoring_Report_508.pdf
This report summarizes ground-, aircraft- and satellite-based snow depth measurement methods, including automated snow depth measurement methods. Highlighted below are selected tables from the publication:

- Table 1. *Ground-Based Technologies Summary*, including descriptions, strengths and limitations of nine separate methods to measure snow depth (page 18 of the report, page 26 of the PDF).
- Table 2. *Air and Space-Based Technologies Summary,* including descriptions, strengths and limitations of six separate methods to measure snow depth (page 25 of the report, page 33 of the PDF).
- Table 6. *Technology Readiness Levels and Cost*, including initial implementation and annual operative costs (page 42 of the report, page 50 of the PDF).

Guidelines for Using Photogrammetric Tools on Unmanned Aircraft Systems to Support the Rapid Monitoring of Avalanche-Prone Roadside Environments, Nathan Belz and Edward McCormack, U.S. Department of Transportation Research and Innovative Technology Administration, January 2021.
https://digital.lib.washington.edu/server/api/core/bitstreams/f0ea0ab7-7b71-4ee7-b6f3-fb084c12fc3c/content
From the abstract: Unmanned aircraft systems (UAS) technology paired with photogrammetric capabilities has the potential to rapidly provide feedback on snowpack data that can be used to monitor and forecast avalanche risks. This research tested Structure from Motion (SfM)(photogrammetry) software with data from unmanned aircraft above roadside avalanche test sites in Alaska and Washington state. The SfM data included accurate information about snowpack depth and snowpack volume, which can help department of transportation (DOT) avalanche experts assess risk and determine whether mitigation was necessary. In addition, the digital images collected for the SfM provided additional useful information. The collection of SfM data has limitations, as successful data collection requires proper ground control points for registration of the images, adequate lighting to collect the digital images required for the SfM process, and the ability to fly the unmanned aircraft to collect the data, which may be limited by both weather and regulations. Overall, the effort determined that SfM provides usable data, and it created a decision support tool to assist DOTs in more quickly responding to and mitigating avalanche hazards, opening roads, or avoiding closing them at all and thus improving roadway reliability for both freight and passengers.

State Research and Resources

Colorado

Snow Depth Retrieval with an Autonomous UAV-Mounted Software-Defined Radar, Samuel Prager, Graham Sexstone, Daniel McGrath, John Fulton and Mahta Moghaddam, Colorado Department of Transportation, April 2023.
https://rosap.ntl.bts.gov/view/dot/80070
From the abstract: We present results from a field campaign to measure seasonal snow depth at Cameron Pass, Colorado, using a synthetic ultrawideband software-defined radar (SDRadar)

implemented in commercially available Universal Software Radio Peripheral (USRP) software-defined radio hardware and flown on a small hexacopter unmanned aerial vehicle (UAV) We image seasonal snow across two transects: a 400-m open Meadow Transect and a 380-m forested transect. We present a surface detection algorithm that fuses data from LiDAR, global navigation satellite system (GNSS)/global positioning system (GPS), and features in the radargram itself to obtain high precision estimates of both snow and ground surface reflections, and thus total snow depth represented as two-way travel time. The measurements are validated against independent ground-based ground-penetrating radar measurements with correlations coefficients as high as ρ = 0.9 demonstrated.

Michigan

Snowpack at UMBS, University of Michigan Biological Station, 2023.
https://sites.lsa.umich.edu/classenlab/2023/12/11/snowpack-at-umbs/
From the website: At the end of November we installed a high frequency snow depth sensor at UMBS [University of Michigan Biological Station]! This simple setup uses a low cost sonic rangefinder to monitor the distance between the bottom of the sensor and the ground beneath it. As snow accumulates, that distance will decrease there for giving us snow depth data. The sensor is powered by a small solar panel and will measure hourly. The sensor node was designed by the Digital Water Lab in the UM College of Engineering led by Dr. Branko Kerkez to monitor river depth in watersheds across the state. We are very lucky to have them lend us a sensor node for terrestrial application and are excited to understand the trends of changing winter.

Montana

Research in Progress: Remote Observation Over Time (Drone in a Box), Montana Department of Transportation, start date: August 2024; expected completion date: September 2026.
Project description at https://www.mdt.mt.gov/research/projects/remote-observation.aspx
From the description: Montana's diverse terrain and weather create unique problems for MDT [Montana Department of Transportation] Maintenance crews. Hazardous areas need to be monitored to assess risks such as avalanche and rock-slide sites. MDT Maintenance and MDT Unmanned Aircraft Systems (UAS) Program would like to explore a portable, fully automated drone solution nicknamed 'Drone in a Box.' This drone would monitor and or map hazardous sites remotely to reduce crew exposure and assess potential dangers to the traveling public.
….

This research would propose to answer the following questions: 1) Is a Drone in a Box solution a cost effective and safer alternative to having maintenance crews physically inspect those areas? 2) Can the Drone in a Box solution be a reliable tool to collect the actionable data MDT needs to make accurate decisions? 3) Can mapping snowpack with a Drone in a Box solution in avalanche prone area's help predict occurrences to better prepare for incidents? 4) Can a Drone in a Box solution be an effective asset in assessing flooding issues during spring runoff?

Other Research and Resources

"Snow Depth Extraction from Time-Lapse Imagery Using a Keypoint Deep Learning Model," C.M. Breen, W.R. Currier, C. Vuyovich, Z. Miao, L.R. Prugh, *Water Resources Research*, Vol. 60, Issue 7, July 2024.
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2023WR036682
From the plain language summary: Snow scientists depend on accurate snow depth measurements for water planning and snow modeling. Time-lapse cameras are inexpensive, can be installed for months at a time in remote regions when winter access may be difficult, and can be programmed to take multiple

images a day throughout the winter. However, these cameras often generate thousands of images that require processing to extract snow depth. Here, we develop a keypoint detection model to facilitate automating the process of snow depth extraction from snow poles installed in front of time-lapse cameras. We expand upon previous approaches to predict the length in pixels, then use pixel to centimeter conversions to extract the snow depth in centimeters. We provide a framework for future analysis of snow depth from time-lapse imagery, helping to improve snow depth monitoring and forecasting.

Automated Remote Sensing of Snow Depth: Snow Sensor Project, National Weather Service, Grand Rapids, Michigan, Weather Forecast Office, 2024.
https://www.weather.gov/grr/snowsensor#:~:text=The%20Snow%20Sensor%20probe%20is,echo%20to%20return%20also%20decreases
This website describes a developmental automated snow sensor project supported by the Grand Rapids Office of the National Weather Service. A snow sensor probe sends ultrasonic pulses to a snow board below. The distance is calculated as a function of time and distance. Data readings are sent to a PC every five minutes. Snow fencing lessens snow drifting and protects the surface being probed from windblown debris.

"How We Measure Snowfall: Daily and Season Snow Totals Explained," Andrew On, Blog Post, Jackson Hole Mountain Resort, November 29, 2023.
https://www.jacksonhole.com/blog/how-we-measure-snow
Jackson Hole Mountain Resort uses raw data from its snow tools, which the Bridger-Teton Avalanche Center (BTAC) operates. The resort also collects its season total from BTAC. Daily and season total snow measurements come from snow study plots on the mountain. A sonar sensor uses sound waves to estimate the new snow total at the plots. A staff member manually measures the estimated snow depth since the last time a study plot was cleared and uses a snow sampler to measure the total snow and the snow water equivalent.

"Virtual Snow Stakes: A New Method for Snow Depth Measurement at Remote Camera Stations," Kaitlyn M. Strickfaden, Marnie L. Behan, Adrienne M. Marshall, Leona K. Svancara, David E. Ausband and Timothy E. Link, *Wildlife Society Bulletin*, Vol. 47, Issue 3, August 2023.
https://wildlife.onlinelibrary.wiley.com/doi/10.1002/wsb.1481
From the abstract: Remote cameras are used to study demographics, ecological processes and behavior of wildlife populations. Cameras have also been used to measure snow depth with physical snow stakes. However, concerns that physical instruments at camera sites may influence animal behavior limit installation of instruments to facilitate collecting such data. Given that snow depth data are inherently contained within images, potential insights that could be made using these data are lost. To facilitate camera-based snow depth observations without additional equipment installation, we developed a method implemented in an R package called edger to superimpose virtual measurement devices onto images. The virtual snow stakes can be used to derive snow depth measurements. We validated the method for snow depth estimation using camera data from Latah County, Idaho, USA in winter 2020–2021. Mean bias error between the virtual snow stake and a physical snow stake was 5.8 cm; the mean absolute bias error was 8.8 cm. The mean Nash Sutcliffe Efficiency score comparing the fit of the 2 sets of measurements within each camera was 0.748, indicating good agreement. The edger package provides researchers with a means to take critical measurements for ecological studies without the use of physical objects that could alter animal behavior, and snow data at finer scales can complement other snow data sources that have coarser spatial and temporal resolution.

"Long-Term Monitoring of the Sierra Nevada Snowpack Using Wireless Sensor Networks," Ziran Zhang, Steven Glaser, Thomas Watteyne and Sami Malek, *IEEE Internet of Things Journal*, Vol. 9, Issue 18, September 2022.
Citation at https://ieeexplore.ieee.org/abstract/document/8977506
From the abstract: Recent developments in the Internet of Things (IoT) technology are revolutionizing the field of mountain hydrology. Low-power wireless sensor networks can now generate denser data in real time and for a fraction of the cost of labor-intensive manual measurement campaigns. The American River Hydrological Observatory (ARHO) project has deployed 13 low-power wireless IoT networks throughout the American River basin to monitor California's snowpack. The networks feature a total of 945 environmental sensors, each reporting a reading every 15 min. The data reported is made available to the scientific community minutes after it is generated. This article provides an in-depth technical description of the ARHO project. It details the requirements and different technical options, describes the technology deployed today, and discusses the challenges associated with large-scale environmental monitoring in extreme conditions.

"How Do You Measure Snow in the Remote Mountain West? Use a Snow Pillow, Of Course," Tom Niziol, *The Weather Channel*, January 29, 2021.
https://weather.com/science/weather-explainers/news/2021-01-29-measure-snow-mountain-west-snotel
Accurate measurements of snow depth and snow water equivalent in remote mountainous locations of the western United States come from 800 stations in the Snow Telemetry (SNOTEL) Network. The network's equipment can gather and transmit its data automatically, powered by only solar cells and batteries, without someone coming up to maintain them for up to a year. Snow depth is measured by an ultrasonic sensor that works by measuring how long it takes for an ultrasonic pulse to travel from the sensor, located several feet above the ground, to the surface of the snow and back. *From the website*:

> The real payoff comes from determining just how much water is in the snowpack. That is done by the snow pillow. Designed to sit on a piece of flat ground, most snow pillows are constructed with sheets of stainless steel that form an airtight container filled with an antifreeze solution. As snow piles up on the steel plates, it weighs it down, displacing the antifreeze, and a sensor measures that hydrostatic pressure. Simply put, the snow pillow measures the weight of the water in the snowpack.

"Spatially Extensive Ground-Penetrating Radar Snow Depth Observations During NASA's 2017 SnowEx Campaign: Comparison with In Situ, Airborne and Satellite Observations,**"** Daniel McGrath, Ryan Webb, David Shean, Randall Bonnell, Hans-Peter Marshall, Thomas H. Painter, Noah Moltock, Kelly Elder, Christopher Hiemstra and Ludovic Brucker, *Water Resources Research,* Vol. 55, 2019.
Publication available at
https://research.fs.usda.gov/treesearch/66944#:~:text=We%20collected%20~1.3%20million%20GPR,remote%20sensing%20and%20modeling%20approaches
From the abstract: Seasonal snow is an important component of Earth's hydrologic cycle and climate system, yet it remains challenging to consistently and accurately measure snow depth and snow water equivalent (SWE) across the range of diverse snowpack conditions that exist on Earth. The NASA SnowEx campaign is focused on addressing the primary gaps in snow remote sensing in order to gain an improved spatiotemporal understanding of this important resource and to further efforts toward a future satellite-based snow remote sensing mission. Ground-penetrating radar (GPR) is an efficient and mature approach for measuring snow depth and SWE. We collected ~1.3 million GPR snow depth observations during the NASA SnowEx 2017 campaign, yielding a spatially extensive (~133-km total length) and high-resolution (~10-cm lateral spacing) validation data set to assess various remote sensing and modeling approaches. We found high correlation between the GPR and manual snow probe derived

snow depths (r = 0.89, p < 0.0001, root-mean-square error (RMSE) = 18 cm), but a median difference of -10 cm, which we attribute, in part, to probe penetration into the unfrozen subsurface. We also compared GPR-derived snow depths to two other independent estimates of snow depth, as an example of how this data set can be used for validation of remote sensing techniques: Airborne Snow Observatory lidar-derived snow depths (r = 0.90, p < 0.0001, median difference = −1 cm, RMSE = 14 cm) and preliminary DigitalGlobe WorldView-3 satellite-derived snow depths (r = 0.70, p < 0.0001, median difference = -3 cm, RMSE = 24 cm).

International Research and Resources

Belgium

"A Machine Learning Approach for Estimating Snow Depth Across the European Alps from Sentinel-1 Imagery," Devon Dunmire, Hans Lievens, Lucas Boeykens and Gabriëlle J.M. De Lannoy, *Remote Sensing of Environment*, Vol. 314, Issue 1, December 2024.
https://www.sciencedirect.com/science/article/pii/S003442572400395X
From the abstract: Seasonal snow plays a crucial role in society and understanding trends in snow depth and mass is essential for making informed decisions about water resources and adaptation to climate change. However, quantifying snow depth in remote, mountainous areas with complex topography remains a significant challenge. The increasing availability of high-resolution synthetic aperture radar (SAR) observations from active microwave satellites has prompted opportunistic use of the data to retrieve snow depth remotely across large spatial and frequent temporal scales and at a high spatial resolution. Nevertheless, these novel SAR-based snow depth retrieval methods face their own set of limitations, including challenges for shallow snowpacks, high vegetation cover and wet snow conditions. In response, here we introduce a machine learning approach to enhance SAR-based snow depth estimation over the European Alps. By integrating Sentinel-1 SAR imagery, optical snow cover observations, and topographic, forest cover and snow class information, our machine learning retrieval method more accurately estimates snow depth at independent in-situ measurement sites than current methods. Further, our method provides estimates at 100 m horizontal resolution and is capable of better capturing local-scale topography-driven snow depth variability. Through detailed feature importance analysis, we identify optimal conditions for SAR data utilization, thereby providing insight into future use of C-band SAR for snow depth retrieval.

Canada

Automated Snow Weather Stations, Government of British Columbia, 2021.
https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-data-tools/snow-survey-data/automated-snow-weather-stations
From the website: Snow depth is measured using an acoustic distance sensor that usually sits 3 – 5 metres above the ground and measures the elapsed time between emission and return of an ultrasonic pulse to determine the distance to the snow. A simple calculation is performed from the summer zero value to then produce the current snow depth.
....

Data recorded by the various sensors is captured by a small computer called a data logger and transmitted via antenna to a NOAA GOES satellite (Geostationary Operational Environmental Satellite), which then passes the information on to a central server from which it is captured by the Government database.

Related Resource:

What Is An Automatic Snow Weather Station (ASWS)? Government of British Columbia, 2016.
https://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/monitoring/river-forecast-centre/what_is_an_automatic_snow_pillow.pdf
From the website: Our British Columbia snow pillows consist of three-metre-diameter bladders containing antifreeze solution. As snow accumulates on the pillow, the weight of the snow pushes an equal weight of the antifreeze solution from the pillow up a standpipe in the instrument house. This weight of the water content of the snow is termed Snow Water Equivalent (SWE). The distance the antifreeze is pushed up the standpipe is recorded by a float connected to a shaft encoder. As well as the vertical standpipe from the pillow, the instrument shelter contains the electronics, consisting of a Data Collection Platform (DCP), a shaft encoder which tracks the movement of the float in the standpipe from the pillow, 12-volt wet-cell batteries for powering the electronic equipment, and regulators for the externally mounted solar panels for recharging the batteries. The DCP contains a transmitter to send the recorded data to the GOES satellite (Geostationary Operational Environmental Satellite). The GOES satellite then transmits the data to the River Forecast Centre's satellite data receiving system in Victoria. On the outside of the instrument shelter are the solar panels for the charging system, and an air temperature sensor.

At most snow pillow sites, precipitation gauges and snow depth sensors are also installed. … The snow depth sensor is mounted on an arm extending from a 6m high tower, and points toward the ground above the pillow. The ultrasonic sensor works similarly to an autofocus sensor in a camera in that it measures the distance from the sensor to the surface below it. As the snow depth increases the distance measured decreases.

"Measurement of the Physical Properties of the Snowpack," N. J. Kinar and J. W. Pomeroy, *Review of Geophysics*, Vol. 53, Issue 2, pages 481-544, June 2015.
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015RG000481
This journal article reviews measurement techniques and best practices and corresponding devices used to determine the physical properties of the seasonal snowpack from distances close to the ground surface. It compares various snow depth measurement instruments, including portable depth rods and rulers, snow tubes, snow pit observations, pressure and load sensors, radar, GPS and laser-ranging devices and optical property measurement devices.

Finland

"Advances in Image-Based Estimation of Snow Variable: A Systematic Literature Review on Recent Studies," Getnet Demil, Ali Torabi Haghighi, Björn Klöve and Mourad Oussalah, *Journal of Hydrology*, Vol. 654, June 2025.
https://www.sciencedirect.com/science/article/pii/S0022169425001933#
This journal article explores deep learning techniques for image-based estimation of snow parameters.
From the introduction:

This systematic literature review aims to provide an overview of the current state of research on the application of image-based techniques for snow cover and snow depth estimation. By synthesizing existing literature, this review seeks to identify key trends, methodologies, challenges and knowledge gaps in the specific area of snow-related hydrological parameters. Through a structured analysis of the literature, this paper aims to inform researchers, practitioners and policymakers about the potential of image-based approaches in enhancing our understanding of snow-related processes and help in improving water resource management strategies in snow-affected regions.

“Snow Depth Time Series Retrieval by Time-Lapse Photography: Finnish and Italian Case Studies,” Marco Bongio, Ali Nadir Arslan, Cemal Melih Tanis and Carlo De Michele, *The Cryosphere*, Vol. 15, Issue 1, pages 369-387, January 2021.
https://tc.copernicus.org/articles/15/369/2021/tc-15-369-2021.html
From the abstract: Historically, snow depth has been measured manually by rulers, with a temporal resolution of once per day, and it is a time-consuming activity. In the last few decades, ultrasonic and/or optical sensors have been developed to obtain automatic and regular measurements with higher temporal resolution and accuracy. The Finnish Meteorological Institute Image Processing Toolbox (FMIPROT) has been used to retrieve the snow depth time series from camera images of a snow stake on the ground by implementing an algorithm based on the brightness difference and contour detection… This study presents new possibilities and advantages in the retrieval of snow depth in general and snow depth time series specifically, which can be summarized as follows: (1) high temporal resolution – hourly or sub-hourly time series, depending on the camera's scan rate; (2) high accuracy levels – comparable to the most common method (manual measurements); (3) reliability and visual identification of errors or misclassifications; (4) low-cost solution; and (5) remote sensing technique – can be easily extended in remote and dangerous areas.

Germany

“Fully Automated Snow Depth Measurements from Time-Lapse Images Applying a Convolutional Neural Network,” Matthias Kopp, Ye Tuo and Markus Disse, *Science of the Total Environment*, Vol. 697, December 2019.
Citation at https://www.sciencedirect.com/science/article/abs/pii/S0048969719341907
From the abstract: Time-lapse cameras in combination with simple measuring rods can form a highly reliable low-cost sensor network monitoring snow depth in a high spatial and temporal resolution. Depending on the number of cameras and the temporal recording resolution, such a network produces large sets of image time series. In order to extract the snow depth time series from these collections of images in acceptable time, automated processing methods have to be applied. … This study investigates the applicability of Mask R-CNN embedded in a newly developed work flow for snow depth measurements. … Since no parameters have to be adjusted, the Mask R-CNN framework is able to detect known shapes reliably in almost any environment, making the presented method highly flexible.

Norway

“Testing Unmanned Aircraft for Roadside Snow Avalanche Monitoring,” Edward McCormack and Torgeir Vaa, *Transportation Research Record 2673*, Issue 2, pages 94-103, February 2019.
Citation at https://journals.sagepub.com/doi/abs/10.1177/0361198119827935
From the abstract: An important part of the Norwegian Public Roads Administration’s (NPRA’s) mission is to monitor and react to snow avalanche hazards in steep areas above their roads. Small unmanned aircraft systems (UASs) are increasingly capable and commercially available. The NPRA wanted to evaluate if this technology could support their avalanche program but had concerns about UASs’ ability to function and to provide usable information in typical field conditions. The NPRA hired vendors to fly nine different UAS aircraft on challenging avalanche surveillance missions in cold, windy weather in steep mountains. An evaluation team’s conclusions were that different aircraft could be effectively used for different aspects of avalanche monitoring and that cameras on UASs (both visible light and infrared) provided images useful for avalanche surveillance. A second test further evaluated if sensors and cameras carried on UASs could provide NPRA’s avalanche staff with usable snow depth, layering, and surface information. Data from UAS carrying visual cameras, used for both real-time viewing and photogrammetry (structure from motion), and ground penetrating radar (GPR) were compared with snow pack information collected using hand dug pits. The review team found the GPR output could

identify the weak snow layers that cause avalanches but the raw data required time-consuming post-processing. Photogrammetry had considerable potential as it mapped snow surface conditions and, with a baseline survey, measured snow depth, both of which are valuable for avalanche assessment. Overall, the review team felt UAS technology held considerable promise to support transportation agencies' roadside avalanche monitoring programs.

Sweden

"Direct Photogrammetry with Multispectral Imagery for UAV-Based Snow Depth Estimation," Kathrin Maier, Andrea Nascetti, Ward van Pelt and Gunhild Rosqvist, *ISPRS Journal of Photogrammetry and Remote Sensing*, Vol. 186, pages 1-18, April 2022.
https://www.sciencedirect.com/science/article/pii/S0924271622000296
The study concludes that UAV-based multispectral photogrammetry using automatic processing routines can provide continuous spatial snow depth representations in an efficient, affordable, and repeatable way. The results support furthermore the underlying research hypothesis regarding the strong potential of multispectral imagery for photogrammetric snow depth estimation in alpine and Arctic terrain while the deployment of Real-Time Kinematic positioning provides the opportunity of spatial data acquisition even in inaccessible areas and makes high-risk and time-consuming in-situ measurements dispensable.

Switzerland

"Monitoring Snow Depth Variations in an Avalanche Release Area Using Low-Cost Lidar and Optical Sensors," Pia Ruttner, Annelies Voordendag, Thierry Hartmann, Julia Glaus, Andreas Wieser and Yves Bühler, *Natural Hazards and Earth System Sciences*, Vol. 25, Issue 4, pages 1315-1330, April 2025.
https://nhess.copernicus.org/articles/25/1315/2025/
From the abstract: Snow avalanches threaten people and infrastructure in mountainous areas. For the assessment of temporal protection measures of infrastructure when the avalanche danger is high, local and up-to-date information from the release zones and the avalanche track is crucial. One main factor influencing the avalanche situation is wind-drifted snow, which causes variations in snow depth across a slope. We developed a monitoring system using low-cost lidar and optical sensors to measure snow depth variations in an avalanche release area at a high spatiotemporal scale. … The results obtained so far indicate that a measurement system with a few setups in or near an avalanche slope can provide information about the small-scale snow depth distribution changes in near real time. We expect that such systems and the related data processing have the potential to support experts in their decisions on avalanche safety measures in the future.

"Intercomparison of Photogrammetric Platforms for Spatially Continuous Snow Depth Mapping," Lucie A. Eberhard, Pascal Sirguey, Aubrey Miller, Mauro Marty, Konrad Schindler, Andreas Stoffel and Yves Bühler, *The Cryosphere*, Vol. 15, Issue 1, pages 69-94, January 2021.
https://tc.copernicus.org/articles/15/69/2021/
From the abstract: Snow depth has traditionally been estimated based on point measurements collected either manually or at automated weather stations. Point measurements, though, do not represent the high spatial variability in snow depths present in alpine terrain. Photogrammetric mapping techniques have progressed in recent years and are capable of accurately mapping snow depth in a spatially continuous manner, over larger areas and at various spatial resolutions. However, the strengths and weaknesses associated with specific platforms and photogrammetric techniques as well as the accuracy of the photogrammetric performance on snow surfaces have not yet been sufficiently investigated. Therefore, industry-standard photogrammetric platforms, including high-resolution satellite (Pléiades), airplane (Ultracam Eagle M3), unmanned aerial system (eBee+ RTK with SenseFly S.O.D.A. camera) and

terrestrial (single lens reflex camera, Canon EOS 750D) platforms, were tested for snow depth mapping in the alpine Dischma valley (Switzerland) in spring 2018. Imagery was acquired with airborne and space-borne platforms over the entire valley, while unmanned aerial system (UAS) and terrestrial photogrammetric imagery was acquired over a subset of the valley. For independent validation of the photogrammetric products, snow depth was measured by probing as well as by using remote observations of fixed snow poles.

Commercial Products

Described below are commercial snow depth sensing products available from three vendors:

- Geolux.
- Hunan Rika Electronic Tech Co., Ltd.
- R.M. Young Co.

NOTE: Information about other commercial products in use — or anticipated to be in use — by the agencies responding to the survey for this Preliminary Investigation appears in the **Survey of Practice** section of this report.

LX-80S Snow Depth Sensor, Geolux, 2023.
https://www.geolux-radars.com/lx-80s-snow
Specifications:

Detection Range: 15 m
Resolution: 0.5 mm
Accuracy: ± 1 mm
Input Voltage: 9 to 27 VDC
Power Consumption: 1.5 W. Standby 0.15 W; sleep 0.03 W; extended 0.6 W
Temperature Range: -40°C to +85°C

From the website: The Snow Depth Sensor uses advanced 80 GHz radar technology to provide precise contactless measurement of snow level from above. It is used for continuous monitoring of snowpack buildup and melting which are essential for hydrological planning, avalanche warning and ski resorts. Unlike ultrasound-based snow level sensors, the measurement accuracy is not affected by rainfall, snowfall, wind or the formation of icicles. Contactless radar technology also enables quick and simple sensor installation above the snow surface and requires minimum maintenance.

RK400-14 Customized Laser Snow Depth Sensor, Hunan Rika Electronic Tech Co., Ltd, 2025.
https://www.rikasensor.com/rk400-14-customized-laser-snow-depth-sensor.html
Specifications:

Detection Range: 0 – 15 m
Resolution: 1 mm
Accuracy: max. ± 1 cm
Input Voltage: 12 VDC
Power Consumption: <0.8W (without heating)
Temperature Range: -40°C to + 50°C

From the website: The principle of the laser snow depth sensor is the optical triangulation method, and the semiconductor laser is focused on the measured object by the lens. The reflected light is collected by the lens and projected onto the CMOS array; the signal processor calculates the position of the light spot on the array through the trigonometric function to obtain the distance to the object.

RK400-14 Laser Snow Depth Sensor, Hunan Rika Electronic Tech Co., Ltd, 2025.
https://www.rikasensor.com/rk400-14-laser-snow-depth-sensor.html
Specifications:

Detection Range: 0 – 1.5 m
Resolution: 1 mm
Accuracy: max. ± 1 mm
Input Voltage: 9-18 VDC
Power Consumption: 300mA
Temperature Range: -40°C to +50°C

SNOdar Snow Depth Sensor (Model 54000), R.M. Young Co., 2025.
https://www.youngusa.com/wp-content/uploads/2025/02/SNOdar-Flyer.pdf
Specifications:

Detection Range: 0.9 – 9 m
Resolution: 0.3 – 1 cm
Accuracy: ± 1 - ± 2 cm
Input Voltage: 6 – 24 volts
Power Consumption: 0.42 – 3.24 W, average 0.5 W
Temperature Range: -40°C to +85°C

From the brochure: SNOdar is one of the only snow depth sensors that utilizes LIDAR (Light Detection and Ranging) technology to provide accurate snow depth measurements. This high-precision method allows the SNOdar to create detailed, real-time snow depth data, ensuring reliable and efficient snow monitoring for a variety of applications.

Contacts

CTC engaged with the individuals below to gather information for this investigation.

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Appendix A: Survey Questions

The online survey represented below was distributed via email to the 39-state member list of the Clear Roads pooled fund study, contacts at selected Caltrans districts and other public agencies.

Caltrans Survey on Automated Snow Depth Collection and Reporting
The California Department of Transportation (Caltrans) is gathering information about the practices used to automate the collection and reporting of snow depth and related measurements.

We estimate the survey will take 15 to 20 minutes to complete. We would appreciate receiving your responses by **Friday, May 16**.

The final report for this project, which will include a summary of the responses received from all survey participants, will be available on the Caltrans website.

If you have questions about completing the survey, please contact Chris Kline at chris.kline@ctcandassociates.com. If you have questions about Caltrans' interest in this issue, please contact Tori Kanzler at tori.kanzler@dot.ca.gov.

Thanks very much for your participation!

(Required) Please provide your contact information.

Name:
Agency:
Division/Title:
Email Address:
Phone Number:

NOTE: Responses to the question below determined how respondents are directed through the survey.

(Required) Does your agency have experience with the automated collection of snow depth data in real time?

- Yes (Skipped the respondent to **Automated Collection Practice**.)
- No (Skipped the respondent to **Wrap-Up**.)

Automated Collection Practice

1. Please describe your agency's practice for the automated collection of snow depth data.

   What and how you measure:
   Timing of measurement:
   Number of collection sites:
   Frequency of collection:
   Start date for the current collection practice:
   Other comments:

2. Please describe the remote monitoring system used to collect data.

   Vendor:
   Product/Tool:
   Other comments:

3. How did your agency determine the ideal time of day to capture measurements?
4. What is the maximum snow depth that can be measured by your agency's remote monitoring system?
5. Please describe the power source(s) used for the remote monitoring system and whether the power source differs based on the remoteness of the measurement site.
6. Please describe the power outages or failures the remote monitoring system has experienced since its placement or over a specified period of time.
7. Please identify the average downtime per remote monitoring site and describe the typical reason(s) for the downtime.
8. How does your agency ensure that the data collected reflects actual snow depth?
9. Does your agency also monitor snow quality?
    - No
    - Yes (Please describe this measurement practice.)
10. Does your agency assess other conditions when remotely monitoring snow depth?
    - No
    - Yes (Please describe these other conditions.)
11. Please describe how the collected data is recorded and managed by your agency.

Assessment

1. Does your agency have experience with a manual measurement method for monitoring snow depth?
    - No
    - Yes (Please describe the manual measurement method and indicate when it was used.)
2. If applicable, please compare the accuracy of remotely gathered data with manual snow depth measurements.
3. What do you like best about your agency's remote monitoring system?
4. What has proved to be most challenging about use of the remote monitoring system?
5. Are you considering any changes to your current remote monitoring protocol?
    - No
    - Yes (Please describe these changes.)
6. Please provide your top three recommendations for another agency planning to remotely monitor snow depth.

    Recommendation 1:
    Recommendation 2:
    Recommendation 3:
7. Please provide links to documents associated with your agency's snow depth remote monitoring system. Send any files not available online to chris.kline@ctcandassociates.com.

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses.